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REPORT

OF THE

WAITE AGRICULTURAL RESEARCH INSTITUTE

GLEN OSMOND, SOUTH AUSTRALIA

1925 - 1932

ADELAIDE
AT THE HASSELL PRESS
1934

The Laboratories of the Waite Agricultural Research Institute.

University of Adelaide

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CONTENTS

PAGE

THE COUNCIL OF THE UNIVERSITY - - - - - - 1

THE STAFF - - - - - - - - - - 2

THE WAITE AGRICULTURAL RESEARCH INSTITUTE

1. Establishment and History - - - - - - 3
2. The Laboratories - - - - - - - 6
3. Farm Buildings and Plant Houses - - - - - 7
4. Scientific Work - - - - - - - 8

THE WORK OF THE INSTITUTE

Agriculture and Plant Problems

1. Field Crop Investigations - - - - - 10
2. Pasture Investigations—Mineral Content of Pastures - - 28
3. Plant Breeding and Genetics - - - - - 39
4. Plant Physiology - - - - - - - 44

Agricultural Chemistry and Soil Research - - - - 49

Entomology - - - - - - - - 54

Plant Pathology - - - - - - - - 67

WAITE ARBORETUM - - - - - - - - 75

PAPERS PUBLISHED BY THE STAFF OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE SINCE ITS FOUNDATION - - - - - 81

METEOROLOGICAL RECORDS - - - - - - - 115

RECORDS OF FIELD EXPERIMENTAL WORK - - - - - 126

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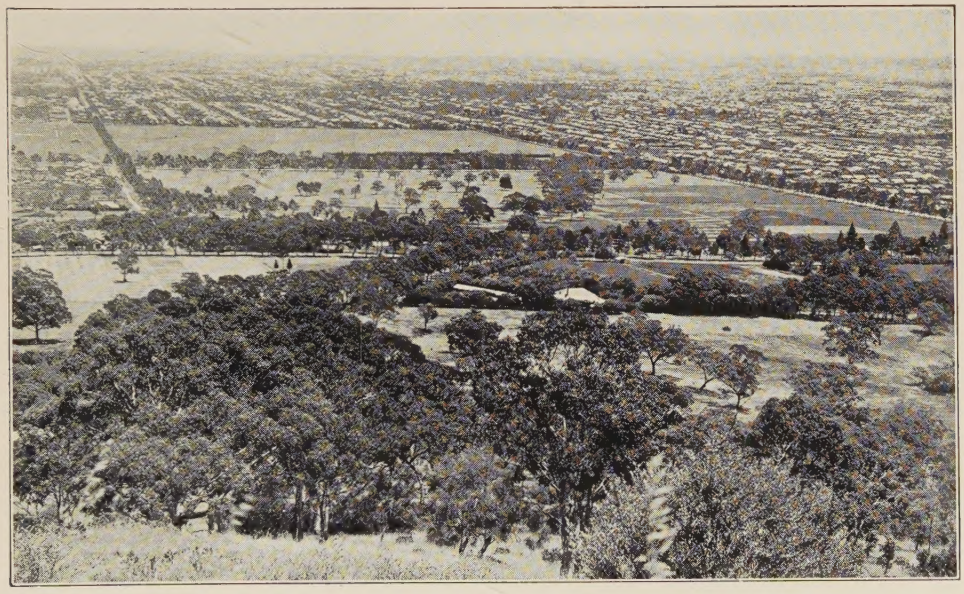
The Waite Agricultural Research Institute

1. Introduction.

The Waite Agricultural Research Institute was established as a result of the late Mr. Peter Waite's gift to the University for the purpose of furthering the cause of education and research in agriculture and allied subjects. The endowment comprises the Urrbrae, Claremont, and Netherby estates, consisting of 299 acres of agricultural and grazing land situated at Glen Osmond, of a mansion house, and a Trust Fund of £58,450. The total value of the bequest was estimated at £100,000.



Waite Agricultural Research Institute, taken from the eastern boundary of the property. 1926.

The estate lies on the scarp of the Adelaide foothills, within four miles of the city of Adelaide. Portion of the estate comprises wheat land, 280-390 feet above sea level, whilst the remainder is representative of the hilly country at the foothills of the Mount Lofty Ranges.

The University Council decided that the best means of giving effect to the wishes of the donor would be to establish an Agricultural Research Institute and endeavour to enlarge the stock of knowledge relating to agriculture in the

widest sense, and pass it on to those actively engaged in production, as farmers or pastoralists. Moreover, the Council decided that for the present the investigations would be confined to plant and soil problems, and to the insect and fungus pests of farm crops. It also appointed its Finance Committee to act as its Board of Management.

The active work of the Institute began in March, 1925. The initial task was the gradual conversion of a large suburban estate into a modern Agricultural Research Station. As the funds available at the inception of the Institute were insufficient to erect and equip the necessary permanent buildings, laboratories were improvised in the existing buildings on the estate, pending the erection of permanent structures.

Sixty acres of arable land on the Urrbrae estate and eleven acres of land on Netherby estate were cleared and converted into permanent experiment fields for the investigation of problems relating to the production of farm crops and improvement of crops and pastures.

A meteorological station and a system garden, containing upwards of 200 species of indigenous and exotic fodder plants, were established in 1925.

A pot culture house, 80 feet by 18 feet, was erected in 1925 to carry out investigations on the water requirements of farm crops.

Practically the entire farming plant required for the initial development of the field investigations came as gifts from agricultural implement makers, and a stone implement shed, 90 feet by 30 feet, was erected to accommodate these implements.

During 1926 the Council for Scientific and Industrial Research, in co-operation with the Waite Institute, undertook to investigate the cause of the tomato wilt disease. The Council erected an insect-proof glasshouse for the purpose of this investigation.

In 1927 the Empire Marketing Board, in co-operation with the Council for Scientific and Industrial Research and the University of Adelaide, jointly agreed to provide funds for the investigation of the mineral content of pastures in Australia. The Empire Marketing Board agreed to contribute a grant of £3,000 towards a laboratory and a sum of £1,875 per annum for a period of five years for this co-operative investigation. The Council for Scientific and Industrial Research contributed £3,000 towards a laboratory for the investigation of the mineral content of pastures and the soil problems associated with the Murray River settlements, and a sum of £937 per annum for five years towards the maintenance costs of the former investigation.

Through the generosity of Sir John Melrose, of Ulooloo, who in 1927 gave £10,000 to the University for the building of a laboratory, the University was able to construct the first group of permanent laboratories for the Institute. The foundation-stone of the John Melrose Laboratory was laid by Miss Lily M. Melrose, daughter of the donor, on January 26, 1928. The building was form-

ally declared open by His Excellency the Governor, Sir Alexander Hore-Ruthven, V.C., on April 22, 1929. Mr. J. T. Mortlock, of Martindale Hall, contributed a sum of £2,000 to the University for the equipment of the laboratories.

A field station was established at the Waite Institute in 1927 by the Council for Scientific and Industrial Research for the investigations of problems relating to Animal Nutrition, under the direction of the late Professor T. Brailsford Robertson. Associated with the field station is a series of sixty pens for feeding sheep, and a metabolimeter room.

In December, 1927, the Parliament of South Australia passed the Agricultural Education Act, which provides for an appropriation for a period of ten years to the University for the development of Agricultural Research at the Waite Institute. Under the terms of the Act the University has agreed to maintain a School of Agricultural Science of degree standard, and to undertake investigations in agriculture and allied subjects, and to provide for advisory services in Plant Pathology and Entomology to the Minister of Agriculture.

In 1928 the Imperial Chemical Industries Limited agreed to provide a sum of £2,000, spread over three years, for the investigation of the effect of nitrogenous fertilizers, and in 1931 and 1932 it made further contributions of £666 13s. 4d. for the same purpose.

In 1928 the Government of South Australia, through the Education Department, granted to the Waite Institute the use for agricultural and grazing investigations of 115 acres of arable land, given by Mr. Peter Waite to the State for the establishment of an Agricultural High School. This area adjoins the Waite Institute, and has been subdivided and developed for the purpose of conducting investigations on farm crops, natural grassland, and seeded pastures.

In 1929 the Commonwealth Bank of Australia agreed to provide a sum of £2,500 conditionally upon the University providing a similar sum towards the cost of a group of buildings, comprising an insectary for the investigation of entomological problems, a plant culture house for investigations in plant physiology, and a laboratory to provide facilities for a range of four glasshouses. The buildings were completed in November, 1929, and were officially opened by R. B. McComas, Esq., a Director of the Commonwealth Bank of Australia on December 9, 1929.

In June, 1929, Mr. Harold Darling gave £10,000 to the University on behalf of the family of the late Mr. John Darling, for the building of a Soil Research Laboratory at the Waite Institute. The Council for Scientific and Industrial Research has agreed to provide the equipment and maintenance of this laboratory, and, jointly with the University of Adelaide, to establish a Division of Soil Research under the direction of Professor J. A. Prescott, at the Waite Institute.

The foundation-stone of the John Darling Laboratory was laid by His Excellency the Governor, Sir Alexander Hore-Ruthven, V.C., on April 14, 1930.

The Laboratory was formally declared open by His Excellency the Governor-General of Australia (Lord Stonehaven) on September 16, 1930.

Under the will of Mrs. Elizabeth Macmeikan, widow, and daughter of the late Mr. Peter Waite, who died on April 5, 1931, her residuary estate, after payment of certain bequests, was left in trust to the University of Adelaide. The net income in the residuary estate is to be paid to the University in perpetuity for establishing and maintaining the study of Agriculture, Botany, Zoology, Veterinary Science, Entomology, Horticulture and Forestry by the University, either in connection with the Waite Agricultural Research Institute or otherwise.

2. The John Melrose and John Darling Laboratories.

The John Melrose and John Darling Laboratories form respectively the south central and north central wings of the laboratories designed for the accommodation of the research staff. The buildings face west, with a fine outlook over the city and suburbs of Adelaide and over the Gulf of St. Vincent.

The central block comprises a large entrance hall, offices, temporary library, common-rooms for the staff, photographic room, and a basement. The basement

Interior of one of the soil laboratories.

has two rooms, one of which, designed to afford a minimum variation in temperature, is devoted to physico-chemical work, and the other accommodates a large dehydrator for the rapid drying with low pressure steam of large numbers of samples of plant material.

The library at present contains 2,154 bound volumes. Subscriptions are made to approximately 60 scientific periodicals, which are received regularly and displayed for the perusal of the staff.

In the collection of bulletins, very material assistance has been rendered by Government Departments, Agricultural Experimental Stations, and other research institutions in various parts of the world. At the request of the Director, these institutions willingly placed the Waite Institute on their mailing lists, and thus presented their publications when issued on the understanding that when any reports of investigations were published by members of the staff of this Institute, a mutual exchange of publications would be instituted.

In November, 1928, the first batch of Waite Institute publications was distributed, and the mailing list now contains the names of 174 institutions which are periodically supplied with the latest reports.

The Melrose Laboratory contains two floors, the ground floor devoted to agronomic and botanical work, and the first floor to chemical work. On the ground floor are one large and two smaller laboratories for agronomy and agrostology, a large laboratory for plant physiology, and a suite of four rooms for plant pathological work.

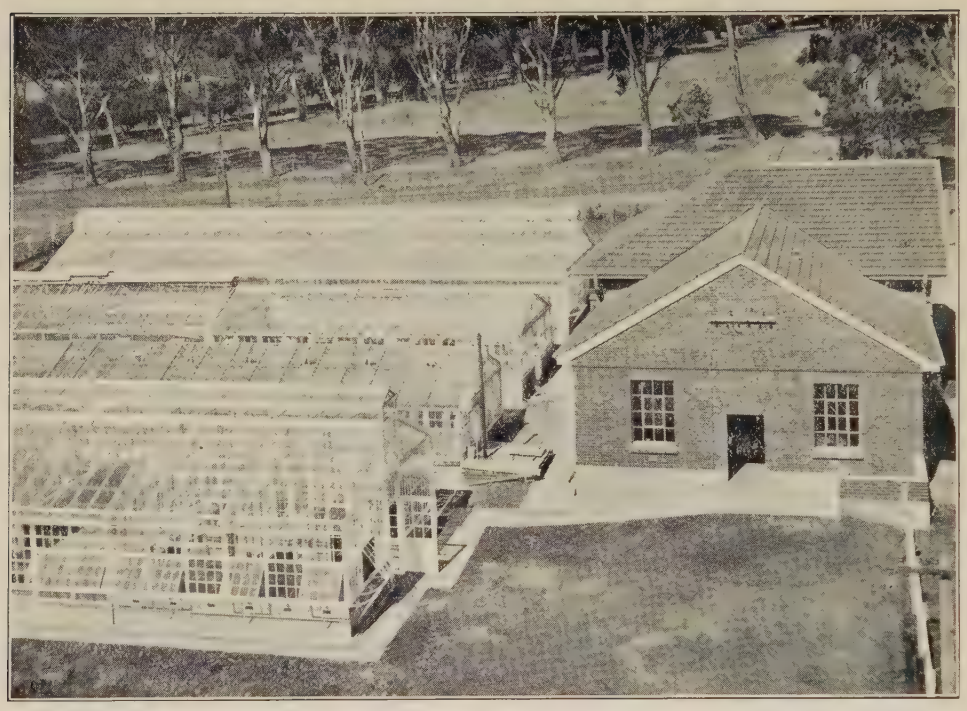
The John Darling Laboratory is practically a replica of the John Melrose Laboratory, except that it has a basement, comprising rooms and laboratories for instructional work for the degree of B.Ag.Sc.

The chemical laboratories consist of the professor's private laboratory, a large laboratory devoted to chemical work with soils, connected through a balance-room with a similar laboratory devoted to pasture problems. A large room planned for soil physics is devoted to the mechanical analysis of soils. A further room is devoted particularly to nitrogen problems.

Provision has been made in the building plan for further extensions of the laboratories as the need arises and as the work of the Institute develops, by the erection of wings adjacent to the Melrose and Darling Laboratories. The present accommodation provides 24,700 square feet of floor space.

3. Farm Buildings and Plant Houses.

The farm buildings comprise a cereal and grain storage house, 96 feet by 30 feet, constructed of brick with tiled roof, a stone implement shed, 90 feet by 30 feet, stables for the accommodation of eight horses, and four cottages for farm labourers.



General view of plant culture houses and insectary.

The group of plant culture houses, situated in an enclosure to the south of the John Melrose Laboratory, comprises a range of four glasshouses, 81 feet long by 24 feet wide, and a plant culture laboratory to serve the needs of these for preparation, storage, and laboratory accommodation. Of these glasshouses, two are used for plant physiological and agronomic investigations, one for plant pathological and one for entomological work.

4. Scientific Work of the Institute.

The main objective of the Institute is to enlarge the stock of knowledge relating to agriculture in the widest sense and to pass it on to those actively engaged in production, as farmers or pastoralists. Expressed in more precise terms, the aim is to conduct researches on plant and soil problems relating to agriculture, and on the insect and fungus pests which affect production.

The Institute also provides an advisory service to the Department of Agriculture in Plant Pathology and Entomology. The University of Adelaide maintains a School of Agricultural Science and courses of instruction for the degrees of B.Ag.Sc. and M.Ag.Sc. Specialized courses of instruction in agriculture, agricultural chemistry, plant pathology, and entomology for these degree courses are provided at the Waite Research Institute.

Though extension work in agriculture is not a function of the Institute, a considerable amount of educational work in agriculture is effected through visits of Agricultural Bureaux, parties of farmers, and other visitors, to the experimental fields and laboratories of the Institute.

The scientific work of the Institute comprises the following:

(A) *Agriculture and Plant Problems.*

The investigation of the problems affecting the production of farm crops; the improvement of pastures; ecological and plant nutrition studies of pasture plants; the improvement of cereals and fodder plants by hybridization and selection; the investigation of problems of mineral metabolism and the relation of nutrition to plant growth.

(B) *Agricultural Chemistry and Soil Research.*

The survey and classification of Australian soil types; the investigation of fertility problems, particularly in the irrigation settlements; and the chemical study of the nutritive value of pastures, with special reference to mineral constituents.

(C) *Entomology.*

Investigation of the insect pests affecting agricultural crops.

(D) *Plant Pathology.*

Investigation of the diseases of agricultural crops, with particular reference to the spotted wilt disease of tomatoes, manganese deficiency disease of oats, and take-all and foot-rots of wheat.

The Work of the Institute

Agriculture and Plant Problems

The most fundamental part of agriculture is the production of crops and pastures, and the researches are directed mainly to the investigation of the principles underlying the practice of farming in a winter rainfall climate, including the tillage of the soil, the manuring of crops and grassland, the rotation of crops, the establishment of pastures and their utilization by the grazing animal, and the production of improved varieties and strains of farm crops and pasture plants.

Approximately 81 per cent. of South Australia has a rainfall of less than 10 inches, and this area is devoted to pastoral pursuits. Over the remaining portion of the State, comprising the agricultural area, the rainfall varies from 10 to over 30 inches. The winter incidence of the rainfall is suitable for the production of cereal crops, but except in the moister regions the dry summer period is unfavourable for the maintenance of permanent pastures of the British herbage species.

The most important agricultural problem is therefore the development of a system of cereal culture and grassland management which will make the utmost use of the seasonal rainfall, and which will be adapted to the exigencies of a semi-arid climate. The results may be applied broadly to a considerable area of country in the winter rainfall zone of Australia.

1. FIELD CROP INVESTIGATIONS.

(1) *Water Requirements of Crops.*

The investigation of the factors affecting the utilization of water by agricultural plants is of particular importance in regions where rainfall limits the production of crops and pasturage. Water requirement investigations have been conducted with farm crops and a number of typical indigenous and exotic pasture species to determine the factors affecting their water economy under cultivation. The amount of rainfall required to produce a given weight of dry matter and grain in farm crops, or total dry matter in pasture plants, was found to vary considerably from season to season. In the case of farm crops, different varieties within the species showed wider differences in the water requirement per unit quantity of grain than in the water requirement for total dry matter.

The transpiration ratio for grain varied within the season according to variety, but also varied widely in the single variety from season to season. These differences in the transpiration ratios were shown to be due to variations

in the intensity of the environmental factors, particularly air temperature, saturation deficit of the air, and wind movements, throughout the active growth period, but particularly during the critical period of maximum growth and transpiration which normally occurs for crop and pasture plants at Adelaide in October.

Interior view of glasshouse used for water requirement investigations of field crops and pasture plants.

A close correlation was found to exist between the rate of transpiration by crops and pastures and the rate of evaporation from a free water surface during this period. Moreover, the effectiveness of the rainfall was lowered by unfavourable factors, such as high air temperature, low atmospheric humidity, and high wind velocity during the period of maximum transpiration.

The investigations revealed that the use of improved varieties of wheat, barley, peas, and subterranean clover, with early maturing habit and a high ratio of seed to total produce, offered a means of adapting the crop to a semi-arid environment. Thus the discovery of early maturing strains of subterranean clover, capable of producing seed under dry spring conditions, has

opened up the possibility of a great extension of the subterranean clover belt in Southern Australia.

Liberal dressings of soluble phosphates were found to accelerate early growth and maturity and to lower the water requirement for grain production. The adjustment of sowing dates to permit better control of weeds, and the production of crops with better balance of grain to straw enables greater production to be obtained on a given rainfall.

The results for eight years at the Waite Institute showed that for each inch of rain transpired by the crop an average of 3·3 bushels of wheat and 5·5 bushels of barley may be produced. The mean effective rainfall during the growing period of the crop for the wheat areas of the State is 11 inches, and the average yield for South Australia for ten years is 1·01 bushels of wheat and 1·59 bushels of barley per inch of seasonal rain. Making due allowance for the increased severity of the environmental factors in less favoured portions of the State, it should be possible to increase the existing yields of wheat and barley to a considerable degree before the limits imposed by the rainfall are approached.

(2) *Permanent Rotation Experiments.*

The conduct of field experiments over fairly long periods is essential to obtain decisive information concerning the possible methods of improving agricultural practice. Differences in yields due to crop rotation, manuring, methods of cultivation, varieties, and time of sowing, are always influenced by the accompanying phenomena—rainfall and its incidence, evaporation rate during critical periods, diseases or pests, etc.—which are liable to change from season to season. Only an average yield of a period of years can be decisive in determining the systems of cultivation, rotation, and fertilization, best adapted for a given environment.

A series of permanent rotation plots was established in 1925 to determine the yield of wheat grown under various systems of rotation cropping in the Adelaide plains environment. The rotation series may be described as a miniature test of different systems of growing wheat, and as far as possible the cultural treatment for each crop in the rotation series is the same as it would receive if grown on a large area.

The normal cultural practice in the wheat belt is to precede the wheat crop with a well-worked bare fallow, and to include, according to circumstances, oats, barley, or temporary pasture in the rotation. In the higher rainfall areas peas or fodder crops fed off with sheep are used in rotation with wheat.

Eleven rotation systems have been tested over the period 1926-1932. The value of these rotational systems can only be determined by their long-term effect on the wheat yield and on the crops grown in rotation with wheat. The results for the years 1926-32 are summarized on page 128.

In six of the rotation cropping systems the main crop (wheat) is preceded by a well-worked bare fallow. The average yield of wheat for this group is 37·8 bushels per acre. In three of the systems the cropping has been continuous, but the wheat is preceded by a pea crop harvested for grain. The average yield of wheat for this group is 35·7 bushels per acre, and of peas, 22·9 bushels per acre. On the other hand, the yield of wheat when grown continuously on the same area has averaged 21·48 bushels per acre.

(3) *Permanent Fertilizer Tests.*

Artificial fertilizers play an important part in increasing the productivity of cereal crops. In the past attention has been concentrated almost entirely on water-soluble phosphates, which have given substantial increases with cereals throughout the wheat belt, and on pastures in the higher rainfall areas.

A series of permanent tests with artificial fertilizers was established in 1925 to determine the immediate and cumulative effect on wheat and barley of varying quantities of soluble phosphate, equivalent dressings of phosphatic fertilizers in the form of superphosphate, basic slag, bonedust, and supplementary dressings of nitrogen, lime and potash. Three groups each of thirty plots were sown with wheat, oats and barley, and each plot has received the same manurial treatment each time the plot has been sown.

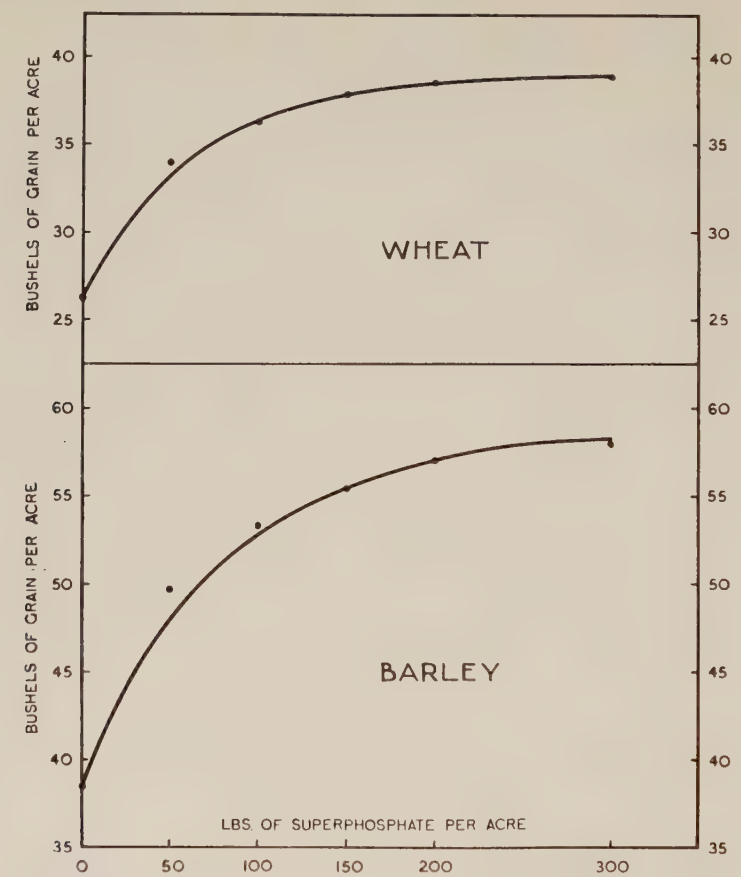
The most significant increases in yield were obtained from superphosphate. The unmanured controls averaged for eight years 26·25 bushels of wheat, 38·52 bushels of barley, and 54·36 bushels of oats. Increasing dressings of soluble phosphate gave increasing yields of wheat and barley up to the highest dressing tested, namely, 280 lb. superphosphate per acre, but with oats there was no material increase beyond 140 lb. per acre. The relationship between the average yield of wheat and barley and the quantity of superphosphate used is summarized in the accompanying graph.

The average increases in yield per acre with 187 lb. of superphosphate for eight years were: Wheat 12·31 bushels, barley 18·45 bushels, and oats 5·37 bushels per acre. Superphosphate thus had a most marked effect on the grain yield of wheat and barley.

Apart from the influence of heavier dressings on grain yields, the indirect effect of the heavier applications in promoting growth on the stubbles is important. Liberal dressings of superphosphate tend not only to give the maximum yield of wheat possible on the rainfall, but they also stimulate the growth of leguminous plants, principally *Medicago* and *Trifolium* spp., e.g. burr clover, cluster clover, on the stubble, and increase the stock-carrying capacity of the farm and the fertility of the soil.

The most marked effect was the stimulus given to the early growth of the crop and to the tillering of the wheat plants. A census count of the number of tillers on unmanured and heavily manured wheat (280 lb. superphosphate per

acre) revealed that the production of tillers was increased by nearly 50 per cent. on the phosphate plot, as compared with the unmanured control. As the number of grains per head and the size of the grain were almost identical on the unmanured and the phosphate-treated plots, the increase in yield due to soluble phosphates was due mainly to the increase in the number of ear-bearing tillers.



AVERAGE YIELD OF (1) WHEAT (2) BARLEY WITH INCREASING QUANTITIES OF SUPERPHOSPHATE WAITE INSTITUTE : 1925-32

An interesting fact which emerged was that superphosphate must be drilled in with the seed to get the full benefit of the phosphate dressing. By drilling superphosphate with the seed the yield was increased by 3·3 bushels per acre, in comparison with the same quantity of superphosphate sown with the drill on the surface of the soil after the seed had been drilled.

Equivalent quantities of phosphoric acid were applied in the form of superphosphate, basic slag, and bonedust. Superphosphate and basic slag, over a period of eight years, gave approximately the same increases in yield both for wheat and barley. On the other hand, phosphate in the form of bonedust gave considerably less wheat and barley than equivalent quantities of phosphate applied as superphosphate and basic slag.

Lime applied at the rate of 1 ton per acre every four years, i.e. equivalent to 5 cwt. per acre a year, gave a substantial increase in yield both for wheat and barley over the corresponding plots without lime. The increases due to the application of lime were 3·98 bushels of wheat and 7·2 bushels of barley per acre.

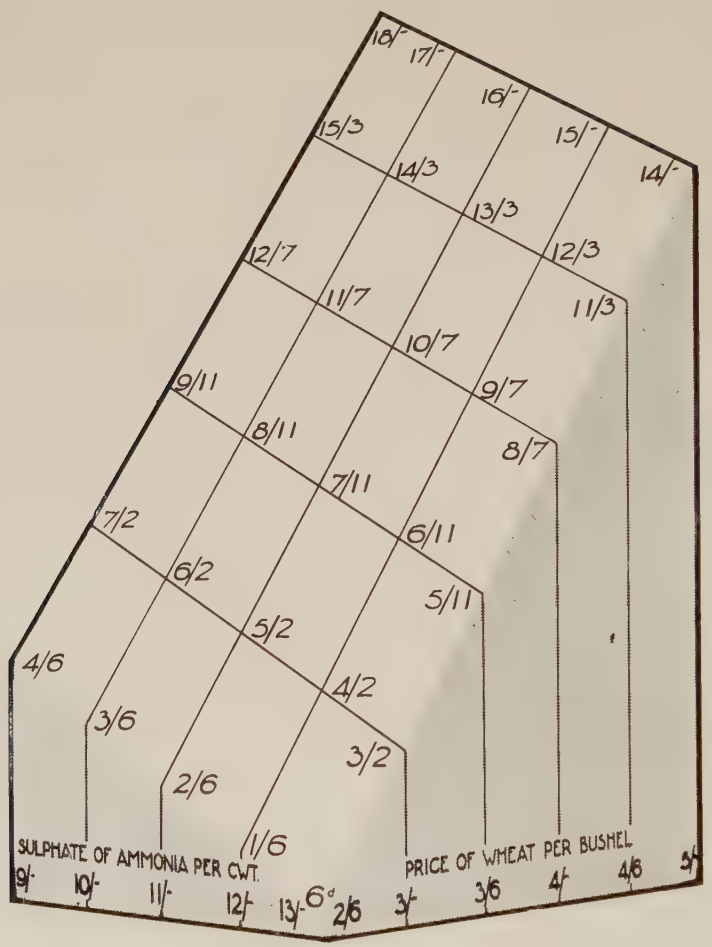
(4) *The Effect of Nitrogenous Fertilizers on Wheat.*

Owing to the remarkable response of Australian soils to soluble phosphates, the problems relating to the use of phosphates have been intensively studied, and in most districts the application of superphosphate, equally with the use of a well-prepared fallow, is regarded as a standard procedure for growing a good wheat crop. The practice of growing wheat after a bare fallow has obscured to some extent the merits of nitrogenous fertilizers as manures for the wheat crop, and incidentally to such crops as are normally sown on stubble, e.g. barley and oats.

The precise physical, chemical and biological changes which take place in a soil during the process of bare fallowing are incompletely known. Investigations, however, have shown that a fallow soil normally contains considerably more nitrate nitrogen at the end of the fallowing period than at the beginning, and that nitrification is particularly active during the early summer and autumn. By seed time the amount of nitrate nitrogen found in the surface layers of a worked fallow in the South Australian environment is sufficient to meet the needs of prolific wheat crops. On the other hand, the conditions in stubble-ploughed land are very different. The available nitrogen, and incidentally the soil moisture, have been practically exhausted by the previous season's crop, and the conditions in the stubble soil during the dry summer are not favourable for nitrification. Hence the nitrate nitrogen content of a stubble soil rarely contains sufficient nitrates to meet the requirements of a good cereal crop, and the application of a nitrogenous fertilizer to a stubble-ploughed soil removes one important limiting factor.

The fallow soil normally contains more moisture at seeding than the stubble-ploughed soil, but the difference between the fallow and the stubble in moisture content is not as great as is generally supposed. For example, over a period of four seasons the difference between the moisture content of the fallow and stubble to a depth of 3 feet at the normal seeding period (June) at the Waite Institute was found to be 1·5 per cent., equivalent to little more than half an inch of rain. This difference in moisture content appears to be of small

importance compared with the serious lack of nitrates in the stubble-ploughed soil, and this view is confirmed by a comparison of the effects of varying quantities of sulphate of ammonia on the yield of wheat over a period of five years (vide page 130).



Solid model showing nett profit per acre from an application of 1 cwt. sulphate of ammonia at varying prices.

The mean increases in total produce and of grain for five seasons due to the application of sulphate of ammonia at the Waite Institute are shown below:

Amount of Sulphate of Ammonia.	Total Produce (cwt. per acre).	Grain (bush. per acre).
56 lb. at seeding	5·2	3·2
1 cwt. at seeding	9·9	5·4
2 cwt. at seeding	19·0	9·1

With no nitrogen the yield was 36·6 bushels of wheat over a period of five years. A dressing of 1 cwt. sulphate of ammonia raised the yield by 5·4 bushels, and 2 cwt. by 9·1 bushels per acre.

The profit resulting from the application of sulphate of ammonia to wheat on the basis of these results is dependent upon the relative prices of grain on the one hand and the cost of the fertilizer on the other. The relationship between profit per acre and wheat and fertilizer prices is shown in the photograph of the solid model. The upper surface of the model indicates the amount of net profit per acre resulting from an application of 1 cwt. of sulphate of ammonia with prices of wheat ranging from 2s. 6d. to 5s. per bushel, and with sulphate of ammonia at prices ranging from 13s. to 9s. per cwt.

Wheat is the most important of the cultivated crops of Australia, the area annually sown averaging 18 million acres. While the greater part of the wheat belt lies within the 10-20 inch line of rainfall, an appreciable portion has a rainfall similar to that of the Waite Institute (23·9 inches). The above experimental results should be capable of wide application to similar wheat-growing areas of Australia.

Again, whilst the normal practice in the older settled areas of the wheat belt is to precede the wheat crop by bare fallow, which does not normally respond to nitrogenous manures, approximately 35 per cent. of the wheat area in South Australia is still grown on stubble land, which probably suffers in varying degrees from a lack of nitrogen. Oats and barley are almost invariably grown on stubble-ploughed land, usually after a crop of wheat or of pasture, and the shortage of nitrate nitrogen may seriously limit the production of these crops.

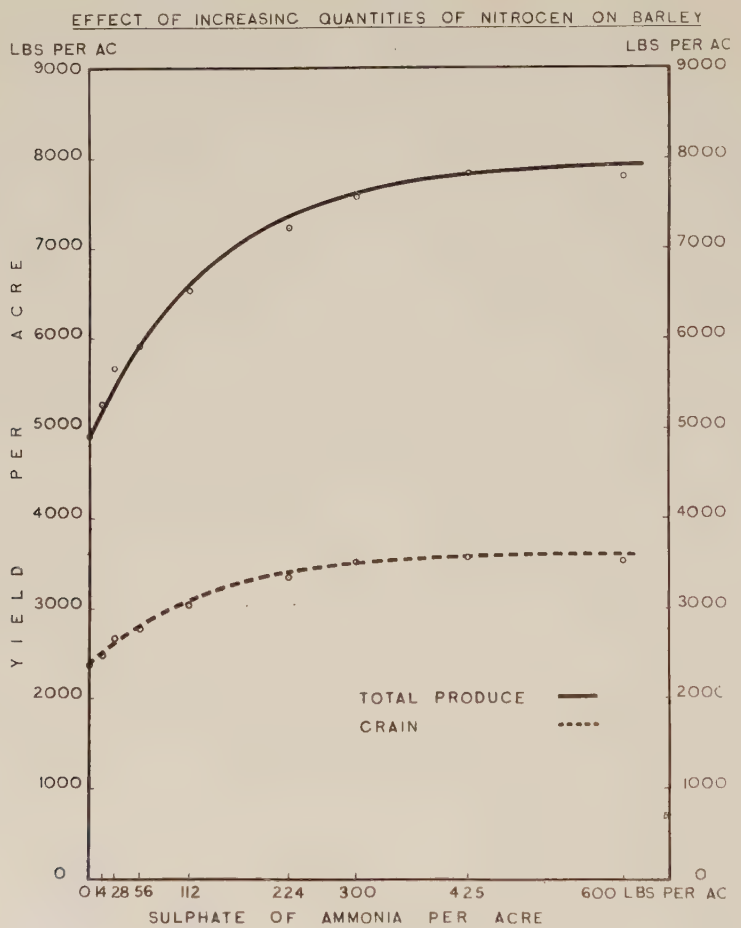
(5) *Effect of Nitrogenous Fertilizers on Barley.*

Wheat occupies a dominant position in South Australian agriculture. It provides the main source of income for thousands of farmers, and the success of the crop largely influences the financial position of the grower. It is not unnatural, therefore, to find that wheat receives preferential treatment in respect to cultivation over other cereals. Whatever bare fallow is available is rightly devoted to wheat, and oats and barley are almost invariably, and necessarily, sown on land more or less hastily prepared from stubble and grass.

Investigation has shown that at harvest the moisture content of the soil under the wheat crop is reduced below the wilting point, and practically the whole of the nitrate nitrogen has been used up by the crop. The dry soil conditions which normally follow the harvest in the South Australian environment are unfavourable for fresh supplies of nitrate nitrogen to be formed in the soil until the seasonal break in the weather occurs in the late autumn. Consequently oats and barley grown on such stubbles cannot produce heavy yields, because of the lack of available nitrate in the soil. If, however, the nitrates are sup-

plied in the form of fertilizer it is frequently possible to raise the yield, particularly of barley, to a level approaching that which would be obtained on a well-worked fallow.

On the permanent manurial field a dressing of 12½ lb. of nitrogen per acre (equivalent to ½ cwt. of sulphate of ammonia), either in the form of sulphate of ammonia or of nitrate of soda, increased the yield of barley grain over a period of eight years by 4·8 bushels (page 129).



Graph showing relation between quantity of sulphate of ammonia applied and yield of barley

Further confirmation of the importance of nitrogen for barley when grown on stubble land may be obtained from the results of a comprehensive investigation of the effect of sulphate of ammonia in quantities ranging from 14 lb. to 600 lb. per acre. In this investigation nine treatments, each replicated and

randomized in the form of a Latin square, were used, and to remove the possibility of soluble phosphate being a factor limiting the growth of the crop, the whole of the plots received a basal dressing of 288 lb. of superphosphate drilled in with the seed.

The effect of these dressings is summarized on page 138, and the accompanying graph shows the quantitative relationship observed between the amount of fertilizer applied and the yield of total produce and grain. The graph provides an interesting example of the law of diminishing returns, or of diminishing increment. With each increase in the amount of sulphate of ammonia applied there is an increase in the yield of total produce and grain, but the first increments of fertilizer are most effective in increasing the yield.

In the light of the above investigations it would appear that the use of sulphate of ammonia offers a means of augmenting the production of feed barley where such is grown on stubble-ploughed land, or of increasing the stock-carrying capacity of the barley crop if it be used for pasture. For the production of malting barley the effect of the sulphate of ammonia on the grain must be considered.

It is well known that the "steely" quality of the grain of a poor sample of malting barley is associated with a high percentage of protein in the grain, and that the "mealy" quality of the grain of a good sample is associated with a low percentage of protein. If the application of sulphate of ammonia to barley increases the nitrogen content of the grain to any marked extent, we should expect to obtain poorer malting samples with increasing dressings of the fertilizer. From the table of results it will be observed that quantities of sulphate of ammonia up to 56 lb. per acre produced no effect on the nitrogen content of the grain. With an application of 1 cwt. and 2 cwt. of sulphate of ammonia the nitrogen content was raised by 0·07 per cent. and 0·17 per cent respectively, and the grain was less valuable as a malting sample. Dressings in excess of 2 cwt. per acre had an appreciable influence in raising the nitrogen content of the grain and in affecting its value as a malting sample.

In any individual year the nitrogen content of the barley grain is subject to variations attributable to the soil on which the crop is grown, the variety, the time of sowing, whilst between two seasons very large differences may be found due to different weather conditions. The differences in nitrogen content of the grain caused by seasonal variations are usually greater than the differences which are obtained by moderate dressings of nitrogen (i.e. up to 1 cwt. sulphate of ammonia per acre).

(6) *The Effect of Nitrogen and Superphosphate on Wheat Grown in Rotation.*

A field investigation was commenced in 1929 to determine to what extent the yield of wheat was likely to be affected when grown after (1) wheat, (2) barley, (3) oats, (4) peas, (5) bare fallow, with and without phosphates and

nitrogen; 240 plots, each 1/24th acre in area, were used for the investigation. During 1929, 120 plots were laid down in 30 blocks of four contiguous plots. Six groups, each consisting of four plots, were fallowed, and each of the following crops was sown in six randomized blocks of four plots each, namely, Sepoy wheat, Cape barley, Brunswick peas, and Early Burt oats. There were thus in 1929, 24 plots under fallow, 24 plots each under wheat, under barley, under oats, and under peas. In 1930 the whole area (excluding the bare fallow plots) was ploughed, cultivated, and the entire 120 plots (including the fallow plots) were sown with Sepoy wheat.

In 1930 a duplicate set of 120 plots was sown under various crops for the growing of wheat in 1931. Within each treatment, wheat after fallow, barley, peas, oats, and after wheat, there were the following treatments: (1) no fertilizer; (2) superphosphate, 2 cwt. per acre; (3) superphosphate, 2 cwt. per acre + sulphate of ammonia, 1 cwt. per acre. The results of the investigation for the three years 1930-1932 are summarized on page 135.

The main features of interest are the mean increases in yield from the various rotation systems with phosphorus, and with phosphorus and nitrogen. These are summarized below:

Mean Increase in Wheat Yield due to Superphosphate (2 cwt.) and Superphosphate (2 cwt.) + Sulphate of Ammonia (1 cwt.) with Varying Systems of Crop Rotation. Three Seasons, 1930-1932.

Rotation	Superphosphate (bush. per acre).	Super + Nitrogen (bush. per acre).
Wheat after wheat	7·8	15·5
Wheat after barley	8·8	15·9
Wheat after oats	7·9	14·4
Wheat after peas	10·4	16·5
Wheat after fallow	19·5	19·7

With fallow land the increased return due to 2 cwt. of superphosphate over a period of three years was 19·5 bushels per acre. With wheat grown on stubble land the increase due to superphosphate was considerably less than half this return, and ranged from 7·8 bushels increase with wheat after wheat to 8·8 bushels per acre for wheat after barley. The response to superphosphate of wheat after peas was 10·4 bushels per acre.

A dressing of 1 cwt. of sulphate of ammonia with the superphosphate gave no significant increase on the fallow, probably because the nitrate nitrogen accumulated during the fallowing process was more than adequate for the needs of the crop. Where wheat was grown after cereals, however, there was a significant and marked response to nitrogen. The dressing of 1 cwt. of sulphate of ammonia increased the yield of wheat by a further 6·5 bushels in the case of wheat after oats, and by 7·7 bushels with wheat after wheat. Even with wheat after peas there was a significant and substantial response to nitrogen.

It would appear from these results that the response of the crop to superphosphate is dependent upon the nitrate nitrogen level of the soil. Where the nitrate nitrogen level is high, as in a well-worked fallow, the maximum response is obtained with superphosphate. With the lower nitrate nitrogen levels, found in stubble-ploughed soil, and where wheat follows cereals, the response of the wheat crop to superphosphate is much less than that of wheat after fallow or wheat after peas.

(7) *The "Staircase" Effect with Nitrogen and Phosphate.*

It has been shown that under certain soil conditions both soluble phosphates and nitrogen are essential for heavy yields of wheat, and that while the response to nitrogen is very marked where wheat is sown on stubble land, that to superphosphate is particularly marked with wheat sown on fallow.

In 1932 a field experiment was laid down to ascertain the effect of sulphate of ammonia, and of superphosphate on wheat sown after oats when the fertilizers were applied singly and in combination.

The effect of superphosphate was tested at four different nitrogen levels, namely, no nitrogen, 1, 2, and 4 cwt. of sulphate of ammonia. Similarly each dressing of sulphate of ammonia was tested with four levels for soluble phosphate, namely, no phosphate, 1, 2, 4 cwt. of superphosphate per acre. Sixteen treatments were employed, each of which was replicated and randomized six times. The results are summarized on page 136.

The increases obtained with the nitrogenous dressings alone are much greater than those obtained with phosphatic fertilizers alone. Evidently nitrogen is a limiting soil nutrient with wheat grown on stubble. The yields of the combined dressings of phosphate and nitrogen confirm this viewpoint, as the largest differences are caused by the nitrogenous dressings, and the phosphatic dressings when combined with nitrogen make very little difference to the yield.

The previous history of the area, however, throws some light on the reason for the response of the crop to nitrogen, and its failure to respond to phosphorus. For three years prior to the laying down of the experiment the area had grown cereal crops which had received annually 2 cwt. of superphosphate. It might be expected, therefore, that the phosphate level should be relatively higher than that of the nitrogen level, and this is well shown on page 136.

The table shows the theoretical increase due to a combined dressing calculated by adding the yields obtained from each single dressing. These theoretical yields are slightly lower than the actual yields obtained with the combined dressing, and the differences are shown on page 136. Comparison by means of a contingency table of the actual and theoretical yields, however, shows that there is no significant difference between the two series of figures. Thus we conclude that the yields due to the combined dressings are purely additive.

The poor response to phosphate as compared to nitrogen probably masks the true relation of phosphorus to nitrogen when these two are deficient. The importance of nitrogen under certain circumstances is, however, well stressed by the above results.

(8) *Cultural Tests with Wheat.*

Bare fallowing is the recognized cultural practice for wheat-growing under Australian conditions. The benefits of fallowing are explained on the following grounds: (a) conservation of moisture, (b) accumulation of nitrate nitrogen in the fallow, (c) reduction of competition with weeds, (d) promotion of tilth and of a firm seed bed for the wheat plant.

It might be supposed that by lengthening the period of fallowing from, say, twelve months to eighteen months, even heavier crops than are grown on normal fallows might be obtained. Such would not appear to be the case under Waite Institute conditions. A series of plots, well worked, was conducted for four seasons, 1927-1930, to compare the yields of wheat, with varying quantities of superphosphate, when grown after: (1) a bare fallow extending over 18 months, (2) a bare fallow extending over 12 months, and (3) land ploughed from stubble at the favourable rain following the harvest, i.e., a short fallow of 4 to 6 months.

The results are summarized on page 133, and show that the extension of the fallowing period beyond 12 months did not increase the wheat yield, though both treatments gave higher mean yields than the wheat sown on a short fallow of 4 to 6 months. A practical difficulty associated with the long fallow was that the soil at seed time tended to become too finely divided and consolidated for satisfactory plant establishment and early growth.

A feature of the experiment was the response of the crop to superphosphate under the different systems of cultivation. This response was considerably greater on the two fallowed areas than that on the stubble-ploughed land. This is particularly true with the heaviest dressings of superphosphate (60 lb. P_2O_5 per acre), the increase over the unmanured control being for stubble-ploughed land 8·82 bushels per acre; 12 months' fallow, 12·1 bushels per acre; and 18 months' fallow, 14·83 bushels per acre.

(9) *Influence of Variety and Time of Seeding on the Wheat Yield.*

The use of a variety of wheat adapted to the climatic and soil conditions of a district has an important influence on the wheat yield. If seasons were uniform in character the choice of a suitable variety would be a relatively easy matter. Seasons, however, vary widely in the amount and incidence of the rainfall, and in saturation deficit of the air at critical periods of the crop growth, and the best one can hope for is to secure varieties which on the whole are suited to the average climatic conditions of the district. This can be directly determined by carefully conducted tests over a period of years. In the drier

wheat-growing areas of Australia the early maturing varieties, which are well on to maturity before the dry weather in late spring sets in, generally give the best results. In districts of liberal rainfall, in which the growing period is more protracted, mid-season and late varieties generally give the best results.

During the early years of the Institute field tests were made with forty of the leading varieties of wheat, including a number of new crossbred types which had achieved prominence in tests by the State Departments of Agriculture. These tests revealed some outstanding varieties for the Adelaide plains district, and, incidentally, the important bearing which the time of sowing has on the yield of the variety. A typical instance may be taken from the records for 1927, in which six of the leading varieties were sown early (May 31), and late (July 11). Each series was replicated six times in the form of a Latin square at each sowing date. The yields were as follows:

	Early Sowing.			Late Sowing.		
Variety.	Total Produce (lb. per acre).	Percentage of Grain %	Grain Yield (bush. per acre).	Total Produce (lb. per acre).	Percentage of Grain %	Grain Yield (bush. per acre).
Gluyas	6,720	24·0	26·8	6,390	32·9	35·0
Rajah	7,550	27·8	35·1	6,290	37·7	40·0
Caliph	7,070	27·2	32·1	6,900	37·8	43·3
Ford	8,680	27·6	39·8	6,540	36·2	38·8
Federation	9,390	31·3	49·1	6,325	40·3	43·2
Sepoy	8,710	33·4	48·5	5,640	41·5	38·5
Mean	8,020	28·6	38·6	6,348	37·7	39·8

The standard error for the early sown plots was 0·96 bushels per acre, and for the late sown series 0·55 bushels per acre. The varieties are arranged in the table in order of earliness of maturity, Gluyas being normally about three to four weeks earlier than Sepoy. With each variety tested the yield of total produce was significantly higher for early sowing than for late sowing, the mean increase in yield being 26 per cent. The percentage of grain to total produce was considerably less with each variety under early sowing, and notwithstanding the marked increase in total produce the mean grain yield was actually less. With early sowing the superiority of the late maturing varieties as grain producers is marked. With the late sown plots the differences in yield between the varieties are less marked, and the early maturing varieties show to greater advantage than with early sowings.

Investigations conducted over a period of three years with early and late sowing at rates ranging from 45 to 90 lb. of seed per acre showed that the optimum sowing rate for Waite Institute conditions was 75 lb. of seed per acre. The mean yield for seven series of tests from a seeding rate of 75 lb. was 31·5

bushels per acre. The yield was reduced by 1 to $1\frac{1}{2}$ bushels per acre as the seeding rate was increased or decreased.

(10) *Uniformity Trials with Cereals.*

In field trials with farm crops there is always an error attached to the result, no matter how uniform the land may appear to be, or how carefully the experimenter may conduct his work. The variations in the yield of a crop from point to point in a field arise mainly from variation in the soil and partly from variations in the incidence of disease and in the effect of competition of weeds. The soil conditions on any given area set aside for field work are thus not the same over the whole area, and it therefore follows that a comparison of a number of treatments on such land will give results which are influenced partly by the given treatment under test, but also by the differences due to soil heterogeneity which are not under the control of the experimenter.

Many studies of soil heterogeneity by means of uniformity trials on similarly treated land have been made, and these all show that soil variability, as reflected in yield per acre, is much more prevalent than was formerly supposed. To reduce the variations in yield which invariably arise from soil heterogeneity a field test should provide not only a means of ascertaining the mean yield due to each treatment under test, but the experiment itself should provide the means of assessing and evaluating the errors due to soil heterogeneity.

An interesting point brought out by a study of crop uniformity trials is the fact that variations in yield over a field are not randomly distributed, but that adjacent plots tend to have similar yields, indicating the presence of a fertility gradient from one portion of the field to another.

It is rarely practicable to precede field tests with a series of uniformity trials to determine the extent of soil heterogeneity on the land on which the field tests are to be conducted. Nor, indeed, are such trials necessary for the conduct of field investigations, as provision can be made in a field trial for measuring the extent of the standard error, and the significance of the differences due to given treatments.

At most agricultural experiment stations field tests covering various phases of agronomic investigation are usually made, and as the area of land available for such tests is limited, an allotment of definite areas for specific investigations becomes necessary. The areas may, and frequently do, show more pronounced variations in crop yield from point to point than are recorded in investigations of selected areas of apparently uniform crops.

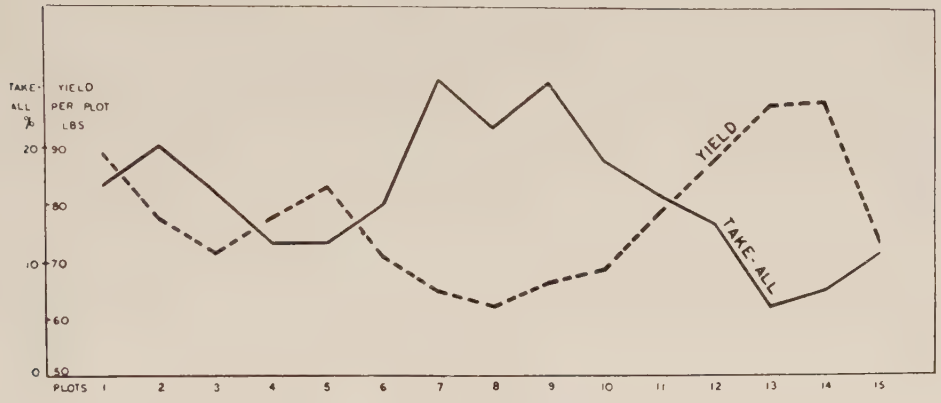
The planning of certain field experiments at the Waite Institute afforded opportunities for the conducting of crop uniformity trials. In 1925 a series of 60 unmanured plots, each of 0·05625 acre, was sown in drill strips 450 links long and $12\frac{1}{2}$ links wide, on land ploughed from natural pasture. Four groups of 15 plots were sown with Nizam wheat, Federation wheat, Algerian oats, and

Cape barley. A parallel series of plots with the same crops was sown on an adjacent range with various manurial treatments.

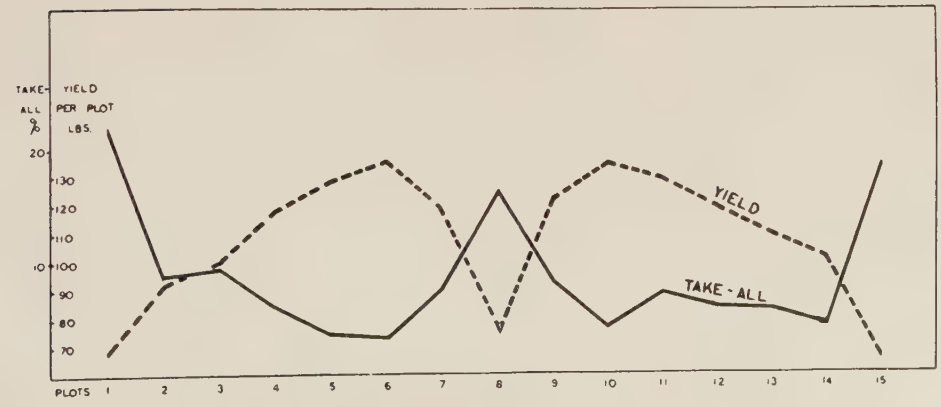
The yields are summarized on page 139, and show that the standard deviation for a single plot was of the order of 15 per cent. for wheat and 12 per cent. for barley, and as low as 4 per cent. for oats in that season.

GRAPH

SHOWING COMPARISON OF INCIDENCE OF TAKE-ALL (OPHIOBOLUS CRAMINIS)
WITH
YIELD OF WHEAT ON UNMANURED & MANURED PLOTS



TAKE - ALL IN 15 UNMANURED PLOTS OF NIZAM WHEAT



TAKE - ALL IN MANURIAL PLOTS OF NIZAM WHEAT

A feature of the wheat manurial plots sown in 1925 on a range adjacent to the unmanured uniformity trials was the effect of soluble phosphates in reducing the percentage of plants seriously affected with the "take-all" disease, *Ophiobolus graminis*. Statistical examination of the percentage of take-all infestation on the manured plots by the Plant Pathologist (Mr. Samuel) showed that when the yield of wheat was high the amount of take-all was low, and vice versa, and that as the dressing of soluble phosphate was progressively increased from 10 lb. P_2O_5 to 60 lb. P_2O_5 per acre, the percentage of take-all present progressively decreased. An examination of the manner in which the take-all fungus influenced the series of unmanured plots showed a correlation of —0·72 for 15 unmanured plots of Nizam wheat, and —0·73 for 15 unmanured plots of Federation wheat. The differential incidence of take-all was in a large measure responsible for the variations in the yield of unmanured wheat plots, all of which received precisely the same cultural treatment.

The heavy infestation of take-all on unmanured virgin land, which had never previously given a crop of wheat, may be explained by the presence of *Festuca myuros* (silver grass), *Hordeum murinum* (barley grass), and *Danthonia semiannularis* (wallaby grass) on the area prior to fallowing. The first two species at least are frequently attacked with take-all, and take-all is commonly found in wheat crops in Australia on land which contains these species, and which has been lying out in pasture for several years. These species tend to form small plant associations of irregular shape, and are rarely distributed evenly throughout a pasture. The distribution of these plant associations in an unbroken pasture is dependent to some extent on soil type. The varying incidence and distribution of a soil-borne fungus disease such as *Ophiobolus* in a wheat crop may therefore be accounted for by the irregular distribution of the host plants carrying the disease, and their distribution in turn is governed largely by variations in soil type. The results of the uniformity trials conducted in 1925 served to indicate the importance of soil-borne diseases as a factor in causing variations in yields of uniformly treated plots.

A second opportunity for the conduct of a uniformity test with wheat presented itself in 1928, when a series of field investigations on the effect of quantities and forms of nitrogenous fertilizers on bare fallow and stubble land was commenced. Three acres of land which had previously grown a wheat crop were required in 1929 to provide stubble land for these investigations. The area was ploughed from "natural pasture" which had been fairly heavily grazed for fourteen years. It was worked down to a standard tilth for the district, and a series of 72 drill strips of Sepoy wheat, each consisting of nine rows of wheat 5 chains long, was sown in June, 1928, without fertilizer. At harvest time the long drill strips were subdivided into units of 1 chain in length, and each of the 360 plots was harvested separately and threshed with a stationary stripper. There was a marked variation in the apparent yield of the plots at harvest, but

it was not possible to make a census of the distribution of disease. Each unit strip measured 1/120th acre in area. The yield distribution of the 360 unit plots is summarized on page 140.

The frequency distribution of the yields of the 360 drill strips of 1 chain conformed closely to the normal curve of error, and a close agreement was found to exist between the theoretical curve and the observed results. The standard deviation for such a single strip was 25·95 per cent. By grouping these unit strips into plots of varying sizes it was found that the standard deviation was not materially reduced in value when the plot size was increased beyond 1/24th acre. Thus for the 5-chain strip of drill plot (1/24th acre) the standard deviation was 16 per cent. By combining adjacent drill strips of 1/24th acre into plots of 2, 3, 4, 6 and 12 units, the standard deviation was reduced to 11·4 per cent. when the size of the plot reached half an acre.

On the whole the long, narrow plot, consisting of a single strip the width of the seed drill, is very suitable for field experiments with cereals, not only for expeditious seeding and harvesting of the plots, but also for making field observations during the growing period of the crop. It is much to be preferred to the short, wide plot of similar area.

The experimental error in field experiments designed to determine the quantitative relation between treatment and yield may be reduced to a reasonable minimum by replication of plots and randomizing the treatments. Systematic replication of the treatments in regular order is often used in field experiments, but while systematic repetition, designed to overcome soil heterogeneity, may reduce the value of the error, it may also reduce its reliability. The method suggested by Fisher, and known as the Latin square arrangement, overcomes both these difficulties, and is the method adopted in the field investigations at the Waite Institute.

A third opportunity for a uniformity test came in 1929, when a series of rotation experiments combined with manurial treatments for wheat was planned. In this case it was desired to measure the yield of wheat when grown in rotation with (a) wheat, (b) peas, (c) oats, (d) barley. As explained in a previous section (page 20), a series of 24 plots of wheat, barley, oats and peas were sown without fertilizer in groups of four plots over the area. The distribution, however, of each group of four plots over the field was randomized.

The results are summarized on page 142, and show that the standard error of a single plot of 1/34th acre was considerably smaller with wheat and barley than in previous trials, but that again the error was not substantially reduced by making the plots twice or even four times the size.

The experimental error in field experiments designed to determine the quantitative relation between treatment and yield may be reduced to a practicable minimum, not by increasing the size of the plots, but by replication of small plots and the random arrangement of the plot treatments.

2. PASTURE INVESTIGATIONS—MINERAL CONTENT OF PASTURES.

Until recently pasture development in South Australia has consisted chiefly in the application of superphosphate to the natural pastures and the establishment of subterranean clover in the higher rainfall areas of the State. At the time when the active work of the Institute was commenced, the question of pasture improvement had received little scientific attention.

Activity in this field was stimulated, however, by the arrangement between the Empire Marketing Board, the Council for Scientific and Industrial Research, and the Waite Institute, to undertake a co-operative investigation of the mineral content of pastures during the years 1927-1932.

The original objectives of the investigation, as approved by the Empire Marketing Board, included detailed studies of (1) natural pastures in mineral-deficient areas, with particular reference to the effect of phosphates on the yield, botanical composition, chemical composition and nutritive value of natural pastures, (2) the factors affecting the mineral content and water requirements of pasture species. The results of this investigation were described in a series of completed papers and reports outlined in the Journal of the Council for Scientific and Industrial Research, *5* (August, 1932).

During the course of this work considerable light was thrown on problems of pasture improvement fundamental to pastoral progress in Southern Australia, and it became evident that there was justification for the extension of the scope of the original investigations to the improvement of pastures by reseeding, manuring and management.

It has been shown definitely that while the environment expressed in terms of climate, soil composition, and pasture management exerts an important influence on the mineral content of the individual plant, there is a limit to the ability of plants to make use of available plant nutrients, which is imposed by the nature of the species itself. It has also been shown that the most economic method of overcoming the mineral deficiency problem on arable land, in regions of moderate rainfall, is to replace the "natural" pasture with permanent species and strains adapted to the soil and climatic conditions, and to maintain their productivity by suitable top-dressing and management. For these reasons work on pure species, strain variation within the species, and pasture management in representative areas of the winter rainfall zone were regarded as a necessary part of the mineral deficiency investigations. This extension of the scope of the original objectives has opened up promising lines of application in the winter rainfall zone of Southern Australia.

A number of papers and reports dealing with various aspects of the work has been published by the Council for Scientific and Industrial Research (Pamphlets Nos. 17, 18; Bulletins Nos. 48, 49, 66, 69, 71; Journal of the C.S.I.R., 1931-32-33). Various other papers have been published in Bulletins of the

Imperial Bureau of Plant Genetics: Herbage Plants (Nos. 7 and 14), and in the South Australian Journal of Agriculture. A detailed list of these publications is separately given (vide pages 95-99). Further papers are in preparation.

In addition to the various phases associated with the mineral content of pastures investigation, work involving the testing of pasture species and strains, the germination of pasture seeds, and the identification of pasture species by means of vegetative characters has been carried out.

(1) *Top-dressing of Natural Pastures with Equivalent Quantities of Phosphoric Acid.*

In view of the particular significance of phosphorus in Australian agriculture, and the extent to which top-dressing of natural pastures is practised, an investigation was commenced in 1925 to determine the effect of equivalent dressings of phosphorus (40 lb. P_2O_5 per acre) in the form of superphosphate, basic slag, rock phosphate, and the effect of a supplementary dressing of nitrogen as nitrate of soda (78 lb. per acre) to superphosphate on a natural pasture. The association was dominated by wallaby grass (*Danthonia* spp.), and was representative of the non-cultivated natural pastures of the Adelaide plains and lower slopes of the foothills. Since 1927 the plots, each of 1 acre, have been grazed individually, but simultaneously, by sheep, and the yield of herbage assessed from the production of ten enclosed quadrats each of $2\frac{1}{2}$ square metres per plot, and harvested as hay at the completion of seasonal growth.

The effects of the fertilizers on the yield of herbage and on the stock-carrying capacity of the pasture are summarized on page 144, and in Publication 71.

While the responses to the fertilizers were marked, certain defects inherent in an exploratory investigation of this type were evident at an early stage, namely, lack of replication, the harvesting of the herbage as hay, and the difficulty of measuring the effect of the pastures on the sheep owing to the small areas employed and their inability to carry livestock over the entire year. A large area of natural pasture was therefore subdivided to follow the changes in seasonal productivity, yield of mineral nutrients, and botanical and chemical composition of the pasture whilst it was grazed by sheep, and to determine the effect of soluble phosphates on the pasture.

(2) *Effect of Superphosphate on the Yield, Botanical and Chemical Composition and Stock-carrying Capacity of Natural Pastures.*

For this purpose 50 acres of natural pasture was subdivided into ten paddocks, each of 5 acres. Six paddocks were left in the natural condition, and four were top-dressed with soluble phosphate at the rate of 40 lb. P_2O_5 (186 lb. superphosphate per acre) for four years.

Two flocks of Merino wethers were maintained for three years on four of the unfertilized paddocks, and two flocks on the four paddocks treated with superphosphate, whilst one flock was alternately grazed on two untreated

paddocks, and received a phosphatic lick as a supplement to the unfertilized pasture.

Throughout the period monthly records were taken of the productivity, botanical composition, and chemical composition of the pasture, the live-weight gains of sheep, and the yield and quality of the wool.

At the same time an area of typical pastoral country deficient in phosphate was selected at Kybybolite (256 miles south-east of Adelaide), and the effect of phosphate on the yield, botanical and chemical composition of the natural pasture, and the live-weight increase, the yield and quality of the wool of Merino sheep was investigated.

The main results of these two investigations, both of which were commenced in 1929, form the basis of a paper by J. Griffiths Davies, A. E. Scott, and K. M. Fraser (in press).

(3) *Management of Natural Pastures.*

The pasture sward is the resultant of the interplay of climatic, soil and biotic factors, the latter including pasture management. Pasture management is within the control of the grazier, and the soil factors are subject to considerable modification at his hands. To obtain information concerning the influence of defoliation of the pasture at various intervals of time on the yield, botanical and chemical composition of a natural pasture, an investigation was carried out in 1927 and 1928.

A sheep-shearing machine was employed as a means of simulating the defoliating action of the grazing animal. Fifty plots, each a square metre in area, were laid down in two blocks, in each of which the plots were randomly distributed on the Latin square system, with 1-metre paths between the plots. The plots were cut at fortnightly, four-weekly, seven-weekly, and ten-weekly intervals, and at the completion of seasonal growth. There were ten replications of each treatment. The results of this investigation are recorded in publication 61.

(4) *Pasture Technique.*

Hitherto little scientific work has been carried out in Australia on indigenous and seeded pastures. Consequently much attention had necessarily to be given to the working out of a satisfactory technique for the investigation of grassland. Methods have been developed to measure the seasonal productivity, grazing value and botanical composition of indigenous and sown pastures under grazing conditions. These are described in Herbage Plants Bulletin, No. 14.

The variability of a natural pasture has been the subject of critical investigation, and the magnitude of the experimental error of varying plot sizes determined. The results indicated that a natural pasture is much more variable than the usual field crop. The optimum size of plot was found to be 450 square links in area and 90 by 5 links in dimension. The standard error of such a plot was found to be 13·75 per cent. of the mean yield. A long, narrow plot tended

to eliminate the effect of plant associations or societies of limited area which were found in most natural pastures.

(5) *Limitations to the Value of Top-dressed Natural Pastures.*

One of the most characteristic features of natural pastures in South Australia is the presence of short-lived, free-seeding annual plants, largely of Mediterranean origin, which assume dominance in pastures which have been top-dressed regularly with soluble phosphates. The type of pasture produced by these annual species is limited in value because of its restricted period of growth, with negligible autumn and poor winter production, followed by excessive development in the spring and heavy loss of seed after ripening.

The production of large quantities of seed is particularly characteristic of these species, and has been measured in relation to the total productivity of the plants at maturity. Values obtained for some common constituents of cultivated and natural pastures by the hand-separation of representative samples are given in the following table.

Proportion of "Seed" produced by Natural and Cultivated Pasture Species at the Waite Institute, 1929-1930.

Natural Species.		Cultivated Species.	
Annuals:	%	Annuals:	%
Brachypodium distachyum	58·1	Wimmera rye-grass (*Lolium* spp.)	26·0
Hordeum murinum	49·2	*Trifolium subterraneum* (early strain)	7·3
Medicago denticulata	47·8	Perennials:	
Trifolium angustifolium	45·2	*Danthonia Duttoniana*	24·9
Erodium botrys	38·3	*Danthonia semiannularis*	22·6
Festuca rigida	34·6	*Lolium perenne*	14·8
Bromus mollis	29·0	*Ehrharta calycina*	11·0
Festuca myuros	27·9	*Dactylis glomerata*	4·8
Trifolium arvense	27·9	*Phalaris tuberosa*	2·6
Trifolium glomeratum	23·4		
Lolium rigidum	21·1		

The "seeds" include the appendages normally present in a hand-separated sample, except in the case of *Trifolium subterraneum* and *T. glomeratum*, where the value given is for true seed. In each of the grasses the "seeds" consist of the caryopses with their adherent paleae. In *Medicago denticulata* the value includes the pod or burr, and in *Trifolium angustifolium* and *T. arvense* the pods and calyces surrounding the seeds were included.

The botanical composition of these natural pastures is dependent almost entirely on seasonal conditions. Methods of improvement must necessarily incorporate a large measure of control over the constituent species, otherwise improvement cannot be maintained for successive seasons. Top-dressing with

fertilizers, harrowing, and grazing by stock are too weak an influence on annual species to counteract the variations in climatic forces met.

The sowing of a mixture of perennial species capable of withstanding summer drought in a dormant vegetative condition offers great advantages over natural pastures. Such pastures have the advantage of stability due to perennial root occupation, which prevents the entrance of undesirable weeds. They are more amenable to control, are capable of providing herbage over a more extended period of the year than annual species, and they respond to summer and autumn rainfall. Furthermore, they are higher fertility demanders, and respond to cultivation, fertilizers and pasture management better than the annual species. Hence a considerable amount of attention has been given to the problem of determining the best species to use for sown pastures in a region of moderate winter rainfall followed by a long period of summer drought.

(6) *Preliminary Tests with Cultivated Pasture Plants.*

The climatic conditions of the agricultural areas in South Australia resemble those of Mediterranean countries and the Pacific coast of America. The European herbage species commonly used for grassland improvement in temperate regions can be established only in limited areas of high rainfall.

One of the first projects undertaken was a test of the species likely to be suitable for pasture improvement in a region of winter rainfall. A grass garden was established in 1925, in which were grown the recognized herbage grasses and clovers, the more valuable native and naturalized pasture plants, and the most promising herbage plants introduced from winter rainfall climates overseas.

Associated with the grass garden were single plant trials of the more promising species carried out under field conditions. The field investigations have been of particular value in demonstrating the single plant characteristics of the tested species and strains, and in eliminating the less suitable types. Approximately 400 species have been grown in these various trials during the past eight years, and it is worthy of note that very few introductions from abroad have proved of greater value than species and strains already established in Australia.

Two perennial grasses, *Phalaris coerulescens*, obtained from the Museum of Natural History, Paris, and *Dactylis glomerata*, var. *hispanica*, collected by a member of the staff (Mr. H. C. Trumble) during a visit to Morocco in 1928, are of promise, but the types of greatest value, namely, *Phalaris tuberosa*, Wimmera rye-grass, hardy strains of perennial rye-grass and subterranean clover have been naturalized in Southern Australia for many years.

(7) *Sward Trials and Pasture Establishment Tests.*

From the inception of the experimental work in 1925 efforts have been made to improve the stock paddocks by the introduction of superior pasture types, and to establish areas of permanent pasture for experimental purposes. These larger scale tests have followed the preliminary trials cited above.

During 1925 areas of natural pasture were top-dressed with superphosphate and sown with commercial subterranean clover. Growth was satisfactory during the season of sowing, but the clover failed to regenerate itself. Several subsequent efforts with commercial subterranean clover seed gave similar results, but with the introduction of a hardy early-maturing strain, which set seed before the advent of dry, hot weather in spring, the successful establishment of this species became possible.

Numerous sward trials under field conditions were made from 1927 to 1929 with the species which from preliminary tests appeared promising. These were sown as pure species in swards and in mixtures of pure species. In nearly all cases development during the seeding year was excellent, but most of the species failed to persist beyond the first summer.

The results of these various sward trials demonstrated that the most promising species for use as pastures in the Adelaide environment were *Phalaris tuberosa*, hardy strains of perennial rye-grass, Wimmera rye-grass, early strains of subterranean clover, wallaby grass (*Danthonia* spp.), perennial veldt grass (*Ehrharta calycina*) and lucerne.

(8) *Investigations of Pasture Establishment at Country Centres.*

Following preliminary trials at the Waite Institute, experimental work was extended in 1930 to outlying centres within the State. Seven centres were established in the areas receiving 18 to 32 inches mean annual rainfall, and work was also carried out under irrigated conditions on the Wood's Point Estate, near Murray Bridge.

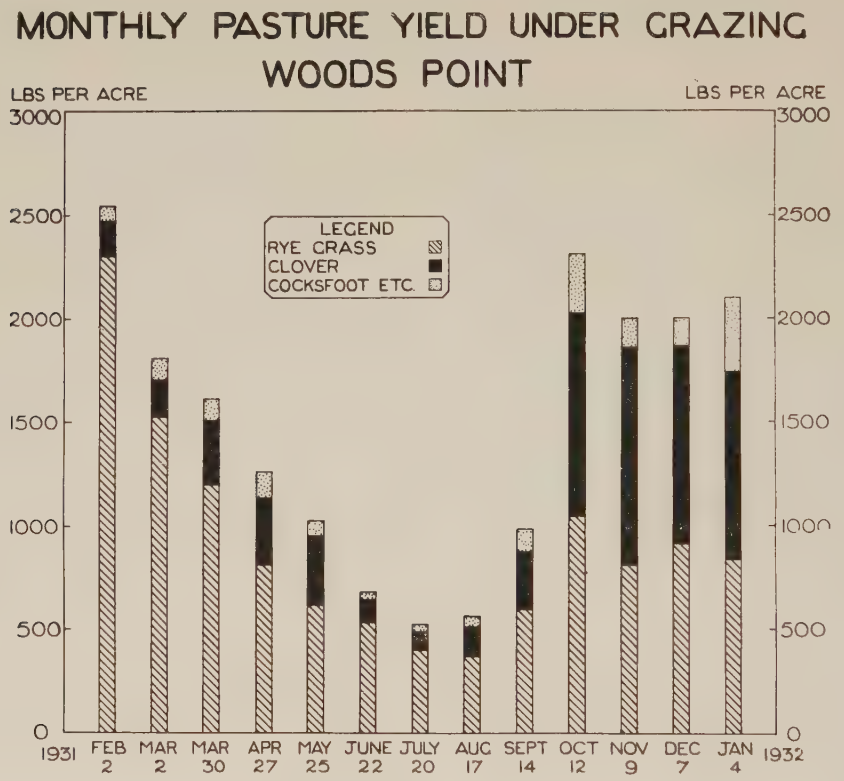
The objectives of the trials were to obtain data on the value of selected species and strains of herbage plants for a representative range of conditions in the better rainfall areas of South Australia. It was considered advisable to employ a comparatively large number of plots at the outset, and broadly to determine the main issues by means of observation rather than to restrict the scope of the trials and conduct more critical tests.

The plots were sown in quadruplicate and randomized within blocks, however, and yield data were obtained from the persistent species during the second and subsequent seasons. In all cases the plots were maintained under grazing control, and were treated as nearly as possible in the same way at all centres. The main results of this work are described in a paper which is in preparation.

(9) *Pasture Management Investigations.*

The productivity of an established pasture is greatly influenced by the system of management, expressed in terms of fertilizer treatment, type of grazing, mowing or cultural treatment, which may be adopted. It is necessary, therefore, to investigate the effect of different systems of pasture management on the yield, botanical and chemical composition of the pasture, provided the initial problems of pasture establishment have been elucidated.

Investigations of pasture management have been carried out on an irrigated sown pasture at Wood's Point, and on a seeded pasture under dry land conditions at the Waite Institute.



Graph showing monthly yield of seeded pasture under grazing, Woods Point. 1931-1932.

The work at Wood's Point was of a detailed nature, and has previously been reported on (Publication 67). The results showed that the production from a mixture of selected strains of perennial rye-grass, cocksfoot, white clover, and red clover was of a high order. Monthly cuts of such a pasture grazed by sheep on a 28-day rotation gave a total yield of 8·7 tons of dry matter per acre during the season following its establishment, and averaged over 25 per cent. protein and 1 per cent. phosphoric acid.

The yield was 34 per cent. greater under grazing than under cutting carried out at similar intervals of time. Moreover, the botanical composition of the pasture was more stable and more satisfactory for livestock under grazing than where periodically cut. Under cutting, the pasture tended to become dominated by clover.

Mowing at 56-day intervals throughout the year gave 31 per cent. more herbage than the sum of the yields obtained from similar pasture mown at 28-day intervals. The nutritive ratio of the feed was better suited for fattening sheep than the narrow nutritive ratio of feed obtained under a system of monthly cuts. The stock-carrying capacity of 70 acres of permanent pasture grazed by sheep over a period of twelve months was 16·2 sheep per acre.

View of sheep grazing on seeded pasture of *Phalaris tuberosa* and early subterranean clover during winter. Pasture management tests, Waite Institute.

At the Waite Institute a seeded pasture established in 1930 with *Phalaris tuberosa,* perennial rye-grass, and early subterranean clover, was subjected to varying types of management. These were as follows: (a) mown four times per season; (b) mown and grazed four times per season; (c) grazed four times per season; (d) cut as hay. The whole area received 2 cwt. of superphosphate per acre per annum, and one-half the plots received sulphate of ammonia in addition.

On the "hay" section the botanical trend was from Wimmera rye-grass dominant in the first season, through a perennial rye-grass phase in the second and third seasons, to *Phalaris tuberosa* dominant in the fourth season. On the systematically mown section, subterranean clover and *Phalaris tuberosa* tended to dominate these plots during the third and fourth seasons, whilst under grazing

the dominance of perennial rye-grass was sustained throughout the four years. The addition of nitrogen as sulphate of ammonia increased the rye-grass content and depressed the clover present in the pasture under all treatments.

The results of this investigation are given on page 146.

(10) *Rotational Grazing Trials with Dairy Cattle (Mount Barker).*

In 1929 an investigation was commenced at Mount Barker (annual rainfall 31·7 inches), to compare the influence of superphosphate and of superphosphate plus sulphate of ammonia on a typical subterranean clover sward characteristic of the hills district. The land available for this purpose was 20 acres, subdivided into eight paddocks of 2½ acres each. The fertilizers were applied in the autumn at the rate of 2 cwt. per acre, and the paddocks were grazed rotationally by two separate herds of dairy cows.

The dominance of the subterranean clover in the pasture during the first season, and the small proportion of grasses in the sward, detracted from the value of the fertilizer comparisons, and in May, 1930, a surface seeding of perennial rye-grass was made. Owing to unfavourable conditions, and the fact that the commercial rye-grass used was a poor strain, the attempt failed. In May, 1931, however, a successful establishment was obtained from a surface sowing of 10 lb. certified New Zealand rye-grass, and, as shown on page 145, there were substantial amounts of perennial rye-grass in the sward in 1931 and 1932. The rye-grass became dominant on the plots treated with the nitrogenous fertilizer.

The number of cow-days of grazing per acre is shown in the table. The application of sulphate of ammonia increased the carrying capacity, mainly in the autumn and winter, by the following amounts: 12·5 per cent. in 1930; 10·5 per cent. in 1931; and 12·2 per cent. in 1932.

(11) *Strain Investigation of Perennial Grasses.*

The *Danthonia, Phalaris* and *Lolium* genera have received fairly detailed attention from the viewpoint of selection and the breeding of improved agricultural strains.

During the 1926 season considerable variation was observed in naturally occurring *Danthonia,* and preliminary collections were made with the object of determining the reaction of *Danthonia* types to conditions of cultivation. The work was extended later to include the selection and breeding of strains. An account of the work is given in Publication 66.

In 1929, when the widespread occurrence of *Phalaris minor* in commercial samples of *P. tuberosa* was first demonstrated, marked variation in type was evident among the single plants of *P. tuberosa* grown in the experimental field. Selective breeding was commenced with this species in 1930. The work carried out with *Phalaris tuberosa* during the 1929-32 period is described in Publications 59, 70 and 72.

Following success with the Hawke's Bay (N.Z.) type of perennial rye-grass in plot trials carried out in 1930-31, a collection of rye-grass types was made in 1931-32, samples being obtained from European countries, New Zealand, and various parts of Australia. These were sown as single plants, and where sufficient seed was available as swards, in 1932. Strain investigation and selection for breeding purposes are at present in progress.

(12) *Mineral Content of Pasture Species Grown in Pot Cultures.*

Much attention was devoted in the early stages of the mineral content of pastures investigation to the determination of the precise effect of various factors which may influence the mineral composition of plants. Such a study was regarded as fundamental to any extensive work in the field.

The investigation took the form of determining the effect of (1) species and strain, (2) stages of growth, (3) soil type and fertilizer application, (4) soil moisture content, on the composition of the pasture. The results of this work are given in Publication 62.

Investigations were also undertaken to determine, under controlled conditions, the effect of growth stage and frequency of cutting on the yield and chemical composition of the herbage, basal internodes, and root system of a perennial grass, *Phalaris tuberosa*. The results appear in Publication 65.

Growth stage was found to exercise a determining influence on the protein, crude fibre, and mineral content of *Phalaris tuberosa*. A downward migration of nitrogen and phosphoric acid was found to occur in this plant from the herbage to the basal internodes and root system. It was found that, during the final stages of growth, potash was lost to the soil in considerable quantities from all portions of the plant. The yields of the herbage, basal internodes, and root system were found to be reduced considerably by increasing the frequency of cutting. The yield of crude protein produced by the grass was increased, however, as the number of cuts was increased. Taking into consideration the yield of dry matter, yield of nutrients, and the permanence of the plant, three cuttings or grazings per season were thought to give optimum results.

The factors affecting the water requirement of pasture plants are of significance in all pastoral regions where the scarcity, unreliability, or irregular incidence of the rainfall limits the production from pastures. Detailed data concerning the water requirement of twenty species of pasture plants and the effect of environment, species, stage of growth, periodic defoliation, fertilizers and soil type on the water requirement of typical pasture plants form the basis of a paper which is in preparation.

(13) *Nitrogen Fixation by Leguminous Plants.*

One of the most striking features of the field investigations of natural and seeded pastures has been the obvious dependence of the pasture for its sustained productivity on the development of pasture legumes. It has therefore become an

important problem to determine the capacity of the more important pasture legumes for nitrogen fixation, and the influence of various factors such as phosphate and nitrogen supply, and the presence of associate non-legumes on the quantity of nitrogen fixed.

Investigations with subterranean clover, burr trefoil (*Medicago denticulata*), and field peas are at present in progress.

(14) *The Germination of Pasture Seeds.*

The optimum temperature conditions for the seed germination of 24 pasture species have been worked out under laboratory conditions. Considerable differences were found in the optimum temperatures required by various groups of pasture plants, ranging from 14°C. in the case of certain *Medicago* and *Trifolium* spp. to 35°C. in certain summer-growing grasses. The majority of the pasture species naturally occurring in the Adelaide environment were found to possess optimum germination temperatures ranging from 15°C. to 20°C.

Apart from temperature, the oxygen-water relations and the conditions of the seed coat influence the germination rate of the seed. In the case of certain seeds special treatment has been necessary in order to obtain satisfactory germination.

(15) *The Identification of Herbage Plants by Vegetative Characters.*

For the positive identification of pasture species it is necessary to find vegetative, or leaf, stem and root characters by which these plants may be recognized at all stages of growth. This has been done at the Waite Institute for the grasses, clovers and trefoils which normally occur in South Australian pastures, and for cultivated pasture plants of recognized value. A total of 40 grasses and 20 legumes has been classified according to their vegetative characters, and positive means are available for their identification in the vegetative condition.

(16) *The Establishment of Saltbushes.*

In view of the special significance of saltbushes in the arid areas of the State, the factors governing their establishment, productivity and drought resistance were investigated, and the extent to which these plants could be utilized in conjunction with pasture improvement work determined (Publication 69). The special value of the saltbushes is attributed to their capacity for production during late summer and autumn, their low water requirement as compared with other fodder plants, and their comparatively high protein and mineral content. Their value is, however, limited by their susceptibility to competition from winter grasses and weeds, and the short-lived perennial character of those species most readily cultivated.

THE WAITE INSTITUTE HERBARIUM.

In 1930 an Herbarium was established with a view of preserving specimens of pasture and fodder plants occurring in the temperate, arid and subtropical zones of Australia. The aim has been to provide a classified and permanent collec-

tion of indigenous and introduced pasture grasses and herbage plants, and to gather information of value from the point of view of plant ecology.

The work of classifying and mounting the specimens was carried out by Mr. A. B. Cashmore, now Agrostologist of the Council for Scientific and Industrial Research.

The herbarium contains 1,584 specimens permanently mounted in folders, and altogether 1,116 species are included. The most valuable part of the herbarium is the collection of indigenous and exotic species of pasture plants, and it has proved to be of great value for workers in ecology and agrostology, and for facilitating the identification of pasture plants forwarded by pastoralists and agriculturists.

3. PLANT BREEDING AND GENETICS.

The welfare of the State is so intimately dependent on wheat that any steps taken to improve the economic basis of the industry will be of advantage to wheat-growers. The adjustment of production costs to prevailing export parities is a difficult problem for the wheat-grower, owing to the resistance offered by fixed and other charges. The costs of cultivation, seed, and fertilizer, and overhead charges are more or less constant, no matter whether the crop produced is large or small. If, however, by improved technique, or by other methods, the yield per acre could at relatively small cost be increased substantially, the costs of production per bushel would be reduced and the outlook for the grower improved.

There are several ways in which increased production per acre may be brought about. Improved cultural methods perhaps offer the best opportunity, especially in the newer settled districts. The breeding of prolific disease-resistant varieties is also of importance, for success in this field would raise the level of production in all districts.

Hitherto wheat-breeders have devoted their attention mainly to the production of high-yielding varieties. Since climatic and soil conditions vary widely in the wheat-growing districts, it could hardly be expected that any one variety would be suited to all districts. Such indeed is found to be the fact. A variety, for example, adapted to the light-textured soils of the mallee would not give the heaviest yield on soils of heavier texture in areas of good rainfall. A wheat-breeding programme should envisage the production of high-yielding varieties adapted to the major wheat districts of the State.

In recent years fungus diseases in wheat have exacted a heavy toll from our wheat crops. Take-all (*Ophiobolus graminis*) and flag smut (*Urocystis occulta*) have been very prevalent, particularly in the newer mallee areas, while red rust (*Puccinia graminis*) greatly lowers the output in seasons with humid conditions during spring and early summer. Early maturing varieties escape to some extent the outbreak of rust, whereas mid-season and late maturing types are

prone to attack when seasonal conditions are favourable to rust. Recent scientific research in the United States and in Australia has disclosed that there are a number of biologic forms of rust, and that certain varieties of wheat are immune to some or all these forms, and that this immunity can be transmitted by hybridization. These researches enable the breeding of rust-resistant varieties to be placed on a scientific basis.

Apart from high yield and resistance to disease, the quality of the wheat cannot be ignored in plans for improvement. Varieties of high baking quality have been produced in Australia by Farrer, Pye, and other workers, but generally speaking these wheats of high baking strength are shy yielders, and are therefore not popular with wheat-growers. An important phase of the problem, therefore, is to associate with high yielding capacity as high a milling and baking quality as is possible.

Owing to the economic importance of the wheat crop, the major project in the plant-breeding investigations at the Waite Institute has been the production of improved varieties of high yielding capacity, and the association of high yield with milling and baking quality and resistance to disease.

Some attention has been given to the production of improved varieties of field peas and of wilt-resistant tomatoes.

(1) Wheat Breeding.

(i) *Plant Introduction.*

Varieties of wheat have been secured from other Australian States and from abroad, with a view of obtaining strains suited to South Australian conditions, but particularly to secure types which, because of special characteristics, such as disease resistance, earliness of maturity, drought resistance, or baking quality, may be suitable as parents for hybridizing with the best local types. For this purpose 376 varieties were introduced from twelve foreign countries and 129 varieties from other States. A noteworthy introduction was the variety Hope, which, though unsuitable for the Australian environment, is highly resistant to disease, and particularly valuable for the production of disease-resistant varieties.

(ii) *Selection Within Varieties.*

Unless a variety of wheat has been subjected to selection for a long period it is highly probable that the variety is a mixture of physiologically and morphologically different races, and is therefore subject to further possible improvement by selection. Thus the original sample of Sepoy wheat received by the Waite Institute was found to be segregating for head type, height of plant, date of maturity, and for various morphological characters. Sepoy has proved to be a prolific variety in the Adelaide environment.

Attempts were made in 1929 to isolate early maturing types. Six of the outstanding selections from sixty pedigreed strains were sown in replicated

field plots in 1932, with the original Sepoy and selected Gluyas. The yields and dates of heading for these tests for 1932 were as follows:

Yield and Date of Heading of Sepoy Selections, 1932.

Strain Number.	Date of Heading.	Yield (bush. per acre).
5074	25/10	47·95
5076	23/10	44·58
5081	19/10	44·13
5079	19/10	43·93
5071	26/10	42·02
5069	26/10	40·31
Sepoy	31/10	40·07
Gluyas	20/10	39·80

The variety Early Gluyas was subjected to the same treatment as was Sepoy. Through the courtesy of the S.A. Department of Agriculture, the Plant Geneticist visited the Minnipa Experimental Farm on Eyre Peninsula in 1928, and made 500 individual plant selections from the crop of Early Gluyas at the Experimental Farm. The best of these selections in field tests in 1932 yielded 44·8 bushels per acre, as compared with 39·8 bushels per acre for the standard variety.

(iii) *Hybridization Followed by Selection.*

The method of hybridization followed by selection is the most useful method for producing improved varieties of wheat, although a period of approximately ten years must elapse before the new variety can be distributed to farmers. A careful selection of parents for cross-breeding has been made, with the object of producing prolific, early maturing, drought-resistant varieties for the drier mallee areas, and prolific mid-season varieties for the better rainfall areas of the State.

The development of new crossbred varieties is just reaching the stage when sufficient seed is available for field testing. Yields of selected strains of hybrid origin sown on fallow in replicated drill plots of 1/70th acre in 1932 were as follows:

Strain Number	Parents.	Date of Heading.	Yield (bush. per acre).
43	Gluyas x Minister	26/10	46·20
35	Gluyas x Minister	24/10	45·14
37	Gluyas x Minister	21/10	42·54
44	Gluyas x Minister	26/10	42·36
45	Federation x Minister	26/10	41·09
	Sepoy	31/10	40·34
	Late Gluyas	20/10	39·80
48	Indian E x Caliph	29/10	39·55
8	Canberra x Gluyas	11/10	38·00
14	Canberra x Gluyas	20/10	36·14
19	Riverina x Federation	13/10	35·40

The climatic conditions of the Waite Institute favour the mid-season to late maturing varieties, so that in assessing the yields of the above strains due attention should be given to earliness of maturity.

It is proposed to grow the most promising strains as determined by the field tests at several centres throughout the State to determine their adaptability to the different districts. The amount of detailed and routine work necessary to establish the superiority of new varieties of wheat of hybrid origin is considerable. The plantings for the past three years may be taken by way of illustration.

Plant Selecting Rows and Field Plots of Wheat, 1930-32.

	1930.	1931.	1932.
Wheat varieties	326	217	230
First Generation Plants (F_1) ..	689	507	501
Second Generation Plants (F_2) ..	19,350	21,750	10,400
Third Generation (rows of wheat) ..	670	915	1,234
Fourth Generation (rows of wheat) ..	801	115	324
Fifth Generation (rows of wheat) ..	103	89	110
Sixth Generation (rows of wheat) ..	—	266	90
Rod Row Selections	1,113	679	695
Drill Strip Plots (1/70th acre) ..	90	51	90
Drill Strip Plots (1/40th acre) ..	—	40	64
Inheritance Studies with Wheat-rows	849	1,543	1,373
Wheat Inoculated with Diseases ..	—	—	255

(iv) *Disease Resistance.*

Among the introduced wheats there are some which are notably free from disease. The American variety, Hope, which is an Emmer cross, is noted for its high degree of resistance to the commoner diseases of wheat, with the exception of take-all. This and other disease-resistant varieties have been extensively used in cross-breeding with Australian varieties, with the object of developing prolific disease-resistant forms.

Artificial epidemics of rust, loose smut, and bunt are created each year among the crossbred progeny, and selections made for yielding capacity from the disease-resistant plants.

(v) *Milling and Baking Quality.*

In 1928 crosses between good quality wheats and our local varieties were made with the object of producing varieties at least equal to our more popular varieties in yielding ability, and superior to them in baking quality.

The application of a recently devised test for baking quality, "the wheat meal time test", to fourth generation selections has revealed that a number of strains of hybrid origin are of moderate to high baking quality, ranging from 140 minutes for a Florence x Baldry hybrid selection to 50 minutes for a Nabawa x Hard Federation hybrid selection. The local varieties, Nabawa, Gluyas, Free Gallipoli, and Late Gluyas, range from 34 minutes for Nabawa to

28 minutes for Late Gluyas. Whether these hybrid strains will yield as well as our local varieties will be determined when sufficient seed is available for a yield test.

(2) Breeding of Field Peas.

In view of the growing importance of the pea crop in South Australia, the production of early maturing varieties is likely to prove of considerable value. The Brunswick White pea, an early maturing variety, is becoming increasingly popular in the wheat districts of better rainfall. The production of earlier maturing varieties of peas may enable the limits of cultivation of this crop to be still further extended into the wheat belt.

In 1929 a collection of 78 varieties of peas was obtained from various States and overseas countries, and crosses made between Brunswick White and the best of the introduced varieties. Sixty fourth-generation selections from these crosses are at present under test.

(3) Breeding of Tomatoes.

(i) *Resistance to Spotted Wilt.*

Spotted wilt of tomatoes is a serious disease in particular years in South Australia, and, since no satisfactory method of control by spraying or dusting has proved effective, an attempt has been made to produce a resistant commercial tomato by crossing the partly resistant currant tomato (*Lycopersicum pimpinellifolium*) with commercial varieties.

A study of the progeny of this cross has revealed that the inheritance of commercial fruit type and wilt resistance is exceedingly complicated. Although 3,000 second-generation plants were examined no selections of commercial fruit type were obtained. Further, the fruit type of those selections resistant to spotted wilt approached that of the currant tomato.

Actually thousands of second-generation plants would have to be grown in order to obtain the combination of commercial fruit type and wilt resistance. In addition, either some certain means of creating an artificial epidemic in the field or a method of testing the resistance of seedlings which would demonstrate the comparative immunity of the currant tomato under conditions of natural infection, would have to be devised. Further work is being held in abeyance until some such method is available.

(ii) *Hybrid Vigour in Tomatoes.*

Hybrid vigour, expressed as yield of ripe fruit, of first generation hybrid tomato plants, was studied in 1931, in five crosses involving Early Dwarf Red as one parent. The yields obtained indicated that the cross, Early Dwarf Red x Break o' Day, produced exceptionally vigorous first-generation progeny, resulting in an increased yield of 38 per cent. over that of the standard Early

Dwarf Red. The hybrid plants were tall, and produced large, smooth fruit of excellent quality.

In the commercial utilization of hybrid vigour only first-generation plants can be used, since segregation of types occurs in the second and succeeding generations. The crosses would therefore have to be made each year, or sufficient seed produced in one year to last for two or more years. This would not be difficult, since hybrids are made with ease, and up to one hundred seeds obtained from one hybrid fruit.

(4) Inheritance Studies.

A knowledge of the inheritance of morphological and physiological characters of the wheat plant is of value to the plant breeder in providing a sounder basis for breeding work. This knowledge can be obtained by the association of studies in inheritance with wheat-breeding projects.

(i) Inheritance studies of earliness of maturity in wheat indicates that this character behaves in a quantitative manner, and that in particular crosses, e.g. Nabawa x Hard Federation, transgressive segregations for date of heading occur with the production of families heading earlier than either parent. Transgressive segregation may therefore be applied to the production of early maturing strains from crosses in which both parents are mid-season or late in maturity.

This phenomenon has been found to occur in other characters, such as height of plant, length of head, and density of head, all of which are utilized by the plant-breeder.

(ii) The maintenance of varietal purity in cereals is a problem which requires considerable vigilance. "Off type" plants may occur in a variety either as a result of accidental mixture with other varieties, by natural cross-fertilization, or as a result of mutation. The former type may be controlled by care at seeding and harvesting, but the latter types occur spontaneously and cannot be controlled.

A detailed study of "off types" in several varieties has revealed that those produced by mutation occur relatively frequently. Genetical and cytological studies of one of these forms have revealed that it is due to the loss of a chromosome (Publication 80).

(iii) The cytology of rye and of wheat-rye hybrids has been investigated (Publications 78 and 81).

(iv) A classification of South Australian wheat varieties has been published (Publication 79).

4. PLANT PHYSIOLOGY.

The investigations on plant physiology are directed towards increasing our knowledge of the fundamental nature of physiological processes.

Special studies have been made of the intake of ions by the plant from the external medium and the relationship of the ions to physiological processes concerned in nutrition and growth.

(1) The Intake of Ions.

A certain amount of work has been carried out on the intake of ions by plant cells, and on the basis of this it is possible to present a schema of some of the factors that may be expected to govern the intake by single cells or by a tissue of uniform cells. However, despite large numbers of isolated observations that have been made on the intake of ions by plants, no general hypothesis has been elaborated in terms of which the process of intake by the whole plant can be visualized. The extension of the above schema to the development of such a hypothesis was therefore desirable. The hypothesis as finally presented is as follows:

Four mechanisms are recognized as responsible for the intake of ions by the plant cell. These are chemical fixation, the holding of ions in Donnan equilibrium in the cytoplasm, the accumulation of free ions in the vacuole at the expense of energy rendered available in respiration, and adsorption. These mechanisms operate in each living cell of the plant, and the rate of supply of ions to the shoots will be determined within limits by the concentrations which are maintained in the sap of the root cells lying in the path of the transpiration stream. This will depend on the rate of respiration of these cells, so that, within limits the rate of respiration of the root cells will determine the rate of supply of ions to the shoots.

This hypothesis is of value in that it can be readily tested by future experimentation. The conception of the relation of ion intake to the respiration of the root is an important one, because the root is normally subject to marked fluctuations in aeration. Experiments were carried out to test the truth of the conception. Oat plants were placed in containers in which the supply of oxygen to the roots was varied, whereby it was found that the root systems respired at different rates. It was found that reduction in respiration rate in general reduced the rate of intake of ions, so that the results conformed with expectation. Professor D. R. Hoagland, of the University of California, has also recently found in unpublished experiments that the intake of ions by excised barley roots is a function of their respiration rate.

(2) The Drift of Content of Inorganic Elements with Age.

The conceptions developed in this work have been extended to the consideration of the drift of the amount of inorganic elements in the plant with age. These drifts are characteristic of annual plants under most conditions, and have been frequently observed both at the Waite Institute and elsewhere. The absolute amounts of potassium, nitrogen, phosphorus and calcium increase

until approximately the time of flowering, after which nitrogen and phosphorus usually remain constant, potassium falls (due to migration out of the plant), and calcium continues to increase until senescence is well advanced. Expressed as percentage amounts on a dry-weight basis, potassium, nitrogen and phosphorus decrease, whereas calcium tends to remain constant.

These drifts have been studied theoretically, and an attempt has been made to interpret them in terms of physiological considerations, based partly on extensions of the hypothesis described in the previous section.

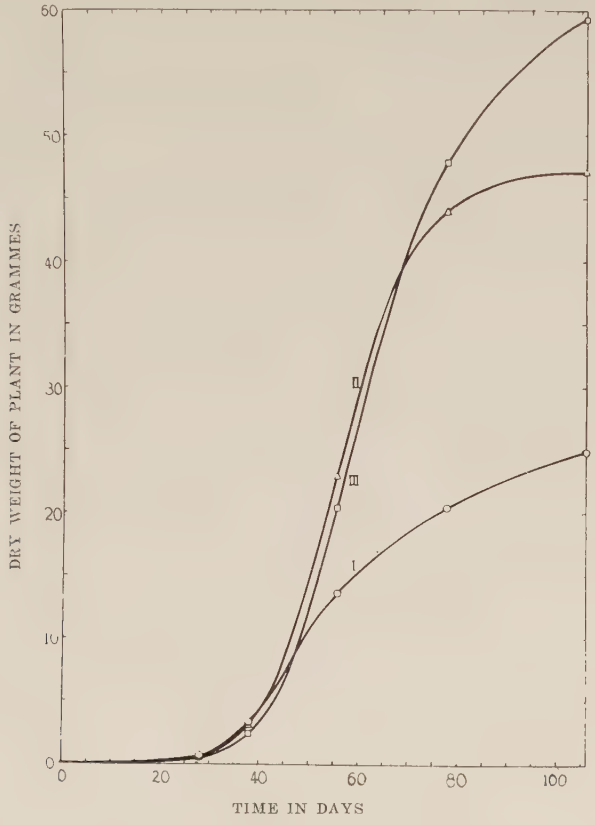
In addition, an experimental study has been made of the drift in the case of potassium and calcium. These two elements are sharply contrasted in that potassium remains entirely unfixed in the plant and retains its mobility, whereas calcium is immobile and undergoes chemical fixation. This accounts for the continued intake of calcium as long as growth is taking place. Potassium being mobile is translocated from the successive old leaves to those that are newly forming, which accounts for a decline in the rate of uptake from the external medium; finally, when the whole plant is senescent potassium is translocated out into the external medium. Analyses of the expressed sap of perennial rye-grass have shown that as the water content of the plant declines in senescence the concentrations of potassium and calcium ions attain very high values. It is suggested that these values are higher than the physiological mechanisms of the plant can maintain. The highly mobile potassium ions are therefore driven out of senescent organs, and migrate either to young tissue or into the external medium. Calcium ions on the contrary, having only a low mobility, are not able to migrate at an appreciable rate.

(3) The Relation of Nutrition to Growth.

Most plants of agricultural importance are of the type whose shoots, if not whole bodies, are of annual duration. Such plants are characterized by a growth curve of sigmoid form. Investigations in progress aim at analysing the growth curve and discovering to what extent its form is determined by nutritional factors. The factors so far under consideration are nitrogen and phosphorus. These being the two main plant nutrients, it is felt that a knowledge of the mechanism of their relation to growth will be of considerable value. The sigmoid growth curve is such that the percentage rate of growth of the plant, or relative growth rate, declines throughout the greater part of the life-cycle. Consideration of the results of experiments in progress and of other work suggests that this decline is closely related to the declining percentage of nitrogen in the plant, and particularly in the leaves, with age, and that the final migration of the nitrogen into the grain is largely responsible for the ultimate death of the plant. A theoretical conception of the factors causing the change in the nitrogen content and its migration in the plant has been developed.

The main method of approach to these nutritional studies has been the

observation in sand culture experiments of the growth rate and various attributes of the plant when different amounts of nitrogen and phosphorus have been supplied. In the case of nitrogen it has been found with barley and Sudan grass that there is a striking effect on the shape of the growth curve. Increased nitrogen supply causes, during the early part of the life-cycle, a depression in



Growth curves of Sudan grass receiving three different amounts of sodium nitrate as follows: I, 0·75 grm.; II, 2·25 grm.; and III, 4·50 grm. per pot.

growth rate, so that the curve is at first lower. Later this depression disappears, and the growth rate is then increased with the treatment, so that ultimately the growth curves cross and the high nitrogen plants give a greater final yield. This is clearly indicated in the accompanying figure. The higher the nitrogen treatment the longer does the depression persist, and if this treatment is sufficiently high it may persist throughout the life-cycle. This state of affairs is exhibited in the well-known descending limb of the curve relating yield to nitrogen supply.

There are then two effects to be considered: an initial inhibition and a subsequent acceleration of growth rate. The latter is a further expression of the already mentioned relationship between percentage nitrogen and relative growth rate; the superimposed initial inhibition has not yet been explained, but is under investigation at the present time.

Experiments are also in progress to determine the relation of phosphorus to the form of the growth curves.

(4) Relation of Transpiration Ratio to the Nitrogen Supply.

It has long been known that the ratio of the amount of water transpired during the life pe[illegible] o the amount of dry matter elaborated, known as the transpiration ratio [illegible] duced by increasing the nitrogen supply. The experiments which have bee[illegible] carried out for the investigation of the relationship of nitrogen supply to grow[illegible]h have provided a basis for elucidating the mechanism of this effect, since [illegible]he weekly water losses of the plants were measured throughout the growing pe[illegible]iod. The possibility that an effect of treatment on the osmotic pressure of the c[illegible]ell sap was produced, such as to decrease the transpiration rate, was ruled out [illegible]n preliminary work on saltbush.

Contrary to expectatio[illegible]n it was found that, measured on a two-day basis, treatment produced no significant effect on the transpiration rate per unit [illegible] The effect on transpiration ratio is wholly due to the effect of [illegible] growth of the plant. It has already been stated that the in[illegible]ate resulting from treatment takes place in the latter part of [illegible]uently it is usually found that at any point prior to that of [illegible]the amount of dry matter produced after that point to the [illegible]fore it is greater, the larger the nitrate supply. Simple m[illegible]ation shows that this fact must tend to a reduction in trans[illegible]. the transpiration rate per unit weight of the whole of the sh[illegible]ge, because the ratio of leaf-weight to total shoot-weigh[illegible]his being a characteristic feature of growth. This causes ar[illegible] tendency to reduction of the transpiration ratio, [illegible]nat the transpiration losses are greatest at a time when the [illegible]tive size of the plants due to the growth phenomenon are most

[illegible]rogen treatment also increases the ratio of weight of leaves [illegible]ght. Since the transpiration rate per unit leaf-weight is un[illegible]s that the rate for a whole shoot is increased. This tends to [illegible]nspiration ratio. The summation of these separate tendencies [illegible]sults in a decrease in the transpiration ratio, although in occasional [illegible] it may cause an increase.

Agricultural Chemistry and Soil Research*

The Department of Soils and Agricultural Chemistry has shown a steady development since the foundation of the Institute. In the early years attention was focussed on soil problems of immediate interest to South Australia, both from the point of view of systematic description and of fertility. Two fertility problems receiving attention were those relating to the lime status of local soils, and the second that of an obscure disease of oats in the Mount Gambier and Penola districts, which was most frequent on soils alkaline in reaction.

The lime status question was most readily approach[illegible] through a study of the hydrogen-ion concentration of the soil, and a gener[illegible]ationship between rainfall and reaction was established, low rainfall being associated with alkaline soils. In very few cases were soils found sufficien[illegible]y acid in reaction to justify more detailed studies of lime requirement, while the very important group of mallee soils—important from the point of view of irrigation and of wheat production—were shown to be predominantly alkaline.

The Mount Gambier problem was investigated in collaboration with the Department of Plant Pathology, and by water cultures, pot experiments, and soil investigations it was established that the disease was a manganese deficiency, due either to a low manganese content of the soil, or [illegible] to a tendency for such manganese present to be maintained in a [illegible] oxidation of low availability. The availability of the manganese [illegible] correlated with the hydrogen-ion concentration of the soil a[illegible] tion-reduction equilibrium.

The more systematic side of the work, that is, a des[illegible] available methods of the physical and chemical features [illegible] soils, was organized by securing the co-operation of t[illegible] of Lands and of Agriculture, whose officers collected so[illegible] g the course of land classification or of fallow competitions. [illegible] nge of amples from the mallee areas particularly were collected [illegible] it ultimately proved possible to describe in considerable detail the information relating to 328 soils from 148 sites in the Stat[illegible] scriptive work had dealt with the volcanic ash of the Mount [illegible] while the future plans concern the study of the red-brown ea[illegible] that is, the group of soils similar to that of the Waite Ins[illegible] occupying a considerable area in the better rainfall zone of t[illegible] South Australia.

In order to secure information regarding the regional distri[illegible] in South Australia, and in view of the well-recognized relationship be[illegible] native vegetation prior to settlement and soil formations, the co-ope[illegible]

* For papers dealing with this section *vide* Publications 1–48 (pages 81–93).

the Surveyor-General was enlisted in 1926, and a map was compiled which showed the distribution of the most important indicator trees and shrubs in the State.

In 1926, at the request of the Council for Scientific and Industrial Research, a preliminary survey of soil problems in the irrigation areas of the Murray and Murrumbidgee valleys was undertaken, this leading in 1927 to the establishment of an investigational unit at the Waite Institute under the title of the

Map of South-Eastern Australia showing localities in which soil surveys have been conducted.

Murray River Soil Investigations. Out of this organization developed the present Commonwealth Division of Soils, which has its headquarters at the Waite Institute, but with officers also resident in Hobart, Tasmania, and Griffith, New South Wales.

An assessment of the problems of the irrigation areas appeared to be only possible along the lines of systematic soil surveys, which would in the first place correlate the behaviour of the horticultural crops, such as citrus, vines and apricots, with specific soil types, and would later enable drainage and irrigation experiments or manurial trials to be designed to elucidate the requirements of

each specific type. The first surveys were begun at Renmark in 1927, and have since extended to other areas, including non-irrigated farming and pastoral country. In addition, some thousands of miles of traverses in Queensland, Gippsland, South Australia, and Western Australia have enabled soil conditions to be compared on a continental basis and a regional soil map of Australia to be prepared. The South Australian aspect of the survey work has dealt with the irrigation areas in the Renmark, Berri, Barmera and Murray Bridge districts, the Hundreds of Laffer and of Willalooka, and portions of the Hundreds of Kuitpo, Rivoli Bay, Mount Muirhead, Symon, Kennion, Short and Riddoch.

In Victoria the most important work has been in the Swan Hill district, while extensive surveys are in progress (1933-34) in the Murrumbidgee irrigation areas.

Other surveyed areas include King Island (Tasmania), Hawk's Nest (Kangaroo Island), Gingin district of Western Australia, and the bed of Lake Albert at the mouth of the Murray.

The total area surveyed to October, 1933, is given below:

	Square Miles.
Western Australia—Gingin	23
South Australia—Non-irrigated Areas	457
Bed of Lake Albert	54
Tasmania—King Island	425
Other Areas	40
River Murray Settlements	87
	1,086

The collection of soil samples at the Waite Institute includes type samples from all the soil surveys except so far as these have been examined by the State laboratories in Melbourne or Sydney, as well as samples representing characteristic profiles from the principal zonal soil formations of the continent, including a range from the desert areas of Australia collected by Mr. Michael Terry, and during the Anthropological Expedition of the University of Adelaide, as well as subantarctic soils collected by Sir Douglas Mawson.

Another group of soil fertility investigations relates to bacteriological activity in the soil, the factors governing the rate of nitrification and the rate of sulphur oxidation having been investigated. The level of nitrate accumulation in the soil plays an important part in the response of field crops to nitrogenous fertilizers, and forms one of the fundamental reasons for the benefit of fallowing under South Australian conditions. Observations have been made since the year 1925 on the conditions in fallowed soils at the Waite Institute, and the fluctuations during the season have been followed up. The rate of nitrification is governed primarily by the soil moisture conditions, the activity being greatest in the surface layers which are cultivated during the process of fallowing. Temperatures are favourable throughout the year, there being in any

case rather a broad range of temperature conditions for optimum nitrification. The reaction to soil moisture conditions is much more sensitive, and during the dry summer period nitrification is in abeyance. There is a definite optimum moisture content between 60 and 70 per cent. of soil saturation; at higher degrees of saturation there is a definite loss of nitrate.

Over a succession of seasons the quantity of nitrate accumulated would appear to approach a constant value of about twenty parts per million for the first 18 inches of soil. The greater portion of this nitrate remains in the first few inches of cultivated soil, and is not washed down until the advent of the regular autumn rains, which appear to be more effective as leaching agents than any subsequent rains, probably owing to the initial dryness of the subsoil.

The oxidation of sulphur in the soil is of principal interest to horticulturists in the Murray irrigation settlements, where for many years gypsum has been used as a soil amendment to the heavier soils. The alkalinity and intractability of many of these soils are associated with a high proportion of sodium in the exchangeable bases, a proportion so high in some of the soils that they respond but slowly to gypsum.

The use of sulphur, which is oxidized in the soil to sulphuric acid, has frequently been recommended, and the progress of this reaction in a Renmark soil has been studied; the optimum degree of moisture saturation for this process of oxidation lies between 60 per cent. and 90 per cent., and the optimum temperature between 12°C. and 35°C. The organism responsible for the oxidation of sulphur in our South Australian soil proved to be a member of the *Thiobacillus* group, previously undescribed, capable of changing the reaction of the soil from pH 8·4 to pH 4·5 in twelve days under suitable conditions. Experiments subsequently carried out at Berri have confirmed the activity of the organism under field conditions, a maximum change from pH 8·3 to pH 5·0 having been observed.

Additional work on soils has related to the technique of the laboratory examination of soils, particularly in order to determine to what extent newer methods being developed elsewhere could be developed to meet local requirements or in the solution of local problems. Such work has included methods for the mechanical analysis of soil, for the determination of hydrogen-ion concentration, and for the estimation of sodium, sulphates and chlorides in soil extracts. Correlations between the mechanical composition of the soil and such single values as sticky point and moisture equivalent, as well as with field estimates of texture, have been investigated.

The possibility of applying methods of electrodrolysis has been explored, but the method is of little value for routine work, owing to the low rate of movement of magnesium, an important constituent of the exchangeable bases in our soils. The method is promising, however, as a means of studying soil constitution.

In addition to soil work, a considerable proportion of time and energy has been devoted to pasture studies. Very little information was available regarding the chemical composition of South Australian pastures, and before any correlations could be attempted it was essential that as much data as possible should be accumulated. Attention has been concentrated on the proximate chemical composition and mineral content of pasture species grown under controlled conditions in the glasshouse, as well as on the composition of grasses, clovers, etc., on specific areas of experimental pasture, mainly at Wood's Point, Mount Barker, and at the Waite Institute.

In order to cover as much ground as possible it has been found advisable to restrict work either to certain phases of pasture growth, such as the flowering stage, or to concentrate on the nitrogen and phosphorus content, these being characteristic of the general nutritive level and mineral content respectively.

A considerable body of information is thus being collected, which will enable pasture management from the point of view of nutritive value to be placed on a more rational basis.

Entomology

The entomological work of the Institute has shown steady development since its inception in 1929. An advisory service to the Department of Agriculture of South Australia has been provided on matters pertaining to entomological problems.

The main work of the department, however, is the conduct of investigations on economic insects in relation to agriculture and horticulture.

During the first year a survey was made of the economic insects of South Australia, and a scheme was developed, in co-operation with the Department of Agriculture, whereby systematic reports on the occurrence of insects of economic importance were obtained. The aim was to publish a brief summary of these records. The relationship between weather conditions and outbreaks of insect pests is a question of great importance in agricultural entomology. Systematic records, over a series of years, relating to the behaviour of the more important economic insects from year to year will yield valuable information in this respect. The first list of observations, covering the period June, 1928, to June, 1930, was published in 1931 (Publication 125). The second list, covering the period June, 1930, to June, 1932, was published in the same journal in October, 1932 (Publication 127).

Detailed investigations have been centred on two main lines of research, (a) certain entomological problems of pasture and cereal crops, (b) certain entomological problems of orchard crops.

1. Insect Problems of Pasture and Cereal Crops.

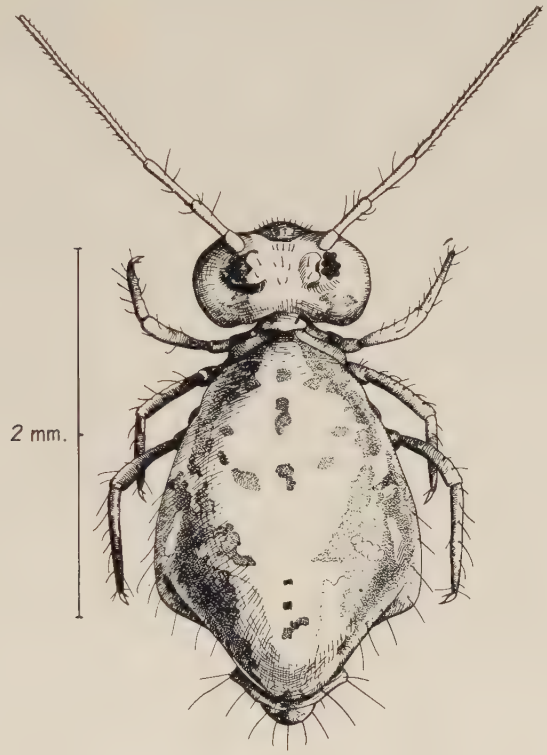
(1) *The "Lucerne Flea", Smynthurus viridis L.*

The "lucerne flea" is the most serious pest of clover and lucerne pastures with which the South Australian farmer has to contend; in favourable wet seasons it is also troublesome to other crops. A detailed investigation of this problem has been carried out.

The pest is a small, primitive insect belonging to a group of insects known as "springtails". It inhabits the soil surface, and multiplies rapidly during the favourable months of the wet season. The insects eat out the green tissues of the leaves of clover, lucerne and many other cultivated plants and weeds. The females lay their eggs in batches, containing about 60 eggs, on the soil surface.

It has been shown that dryness inhibits development of the eggs, and they remain viable in the soil during the dry season. They hatch with the autumn rains, and three or four generations of the species occur during the wet season. With the onset of the dry season the insects die out, and the eggs laid by females of the last generation remain viable during the summer.

The dense population of *S. viridis* which occurs in pastures in South Australia, particularly in the autumn and spring months, is due to the favourable moisture and temperature conditions during these periods. During the mid-winter months the mortality of the eggs and young insects is high; therefore in most districts the population is lower.



The lucerne flea *(Smynthurus viridis)*.

It is owing to the fact that the over-summering eggs hatch out about the same time in autumn, and the favourable conditions in the immediate succeeding months, that the insects increase in such large numbers.

A detailed study has been made of the influence of moisture and temperature in the pasture on the density of the population. Soil type is important in relation to its water-holding capacity, and whether it is alkaline or acid in reaction. The insects prefer soil having a reaction about pH 5·5 to 7·0, and they multiply best on these soils, provided moisture conditions are favourable.

Moisture is the dominating influence affecting the seasonal occurrence and distribution of the species in South Australia; temperature influences the rapidity with which the species passes through a generation. It has been found

that the most favourable months for its increase in numbers are those in which the mean monthly temperature extends between 52°F. and 60°F., when the rainfall is adequate to maintain suitable moisture in the pasture.

By analysing rainfall data and temperature records it has been possible to map out the areas in South Australia in which the species will be of economic importance. Also the months in which it can increase in economic numbers.

The results of these detailed studies have made possible the development of rational measures for control of the species.

Subterranean clover damaged by young nymphs of the lucerne flea *(Smynthurus viridis)*.

In restricted areas of pasture spraying with lime-sulphur, 1 gallon in 50 to 60 gallons of water, at the rate of about 80 gallons to the acre, has given complete control. It is necessary to time the application of the treatment in relation to the habits of the species. The application should be made within about three weeks after the over-summering eggs commence to hatch in the autumn. By this means the first generation of individuals is killed before the eggs are laid. The crop must be cut or close grazed before treatment, so that the spray may come into intimate contact with the insects. Furthermore, reinvasion of the crop by insects coming from the surrounding areas must be prevented.

Where a stand of subt[illegible] or lucerne is being established, an autumn and early winter [illegible]low will clear the area of "lucerne flea". The in-

sects hatch out from the over-summering eggs, and die in the absence of suitable food plants, or wander to adjoining areas. A cereal crop following clover or lucerne is liable to serious damage by "lucerne flea" in its early growth, unless fallow precautions are taken. The eggs present in the soil hatch out, and the insects attack the young cereal plants.

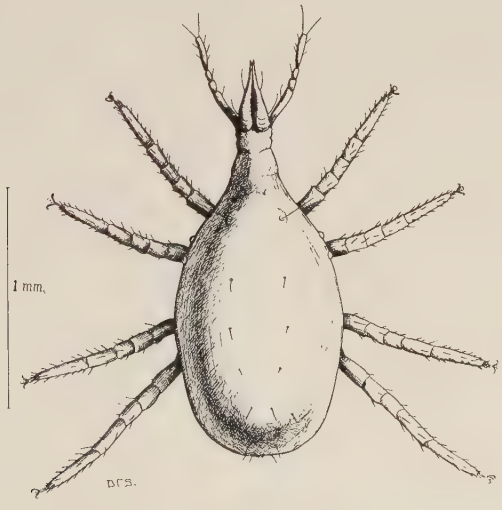
Where judicious surface irrigation in summer is possible in small areas of lucerne or other pasture, the crop can be kept free of *S. viridis*, provided reinvasion from the outside areas is prevented. Adequate moisture must be maintained in the crop by frequent light irrigations. The insects hatch out from the eggs, but as the summer temperatures are unfavourable for them they die without laying eggs. When the autumn rains begin there are no viable eggs present in the crop

Chain harrowing or heavy stocking during the appearance of the first generation of the insect in autumn will help to restrict the increase in numbers of the insects. The method must be correctly timed, as in the case of spraying.

With larger pasture areas the methods described above are impracticable. Local moist situations liable to heavy infestations by the insects may, however, be treated in this way.

Modification of pasture management so as to obtain the establishment of suitable grasses, such as *Phalaris* and rye-grass with clovers, is desirable in larger areas. The grasses afford adequate grazing during the winter months, and with the warmer spring months the clovers will grow away from attacks by the insects.

The possibility of using insect and allied predators as a means of checking the increase in numbers of the lucerne flea is being investigated. It may be



The snout mite *(Biscirus lapidarius)*. A predator on the lucerne flea.

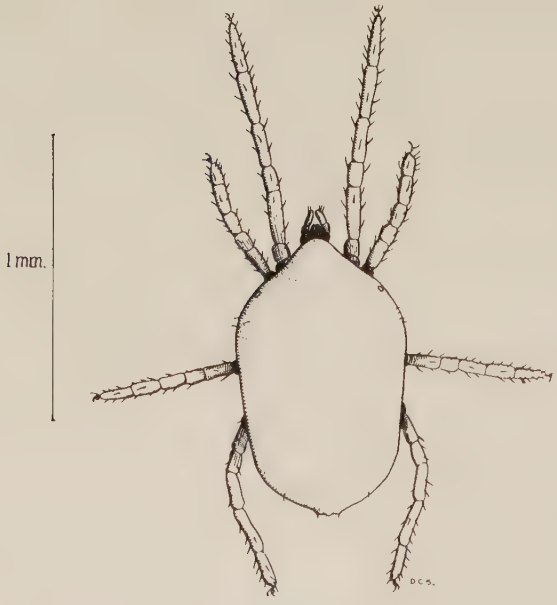
observed that the pasture areas in the State are of recent development, and the variety of insects in them is not so great as obtains in old-established pastures. On the other hand, compared with pastures in England, for instance, the insects which will become established in pastures in South Australia must be able to aestivate during the dry season. Therefore the class of predators which may be used in combating the "lucerne flea" will be restricted. In association with the Council for Scientific and Industrial Research, field experiments are being carried out with a predatory mite, *Biscirus lapidarius*, a member of the snout mite family (Bdellidae).

Owing to the presence of eggs in surface soil and debris, this is a source of spread of the lucerne flea. Experiments have shown that the eggs may be killed by fumigation with carbon-bisulphide.

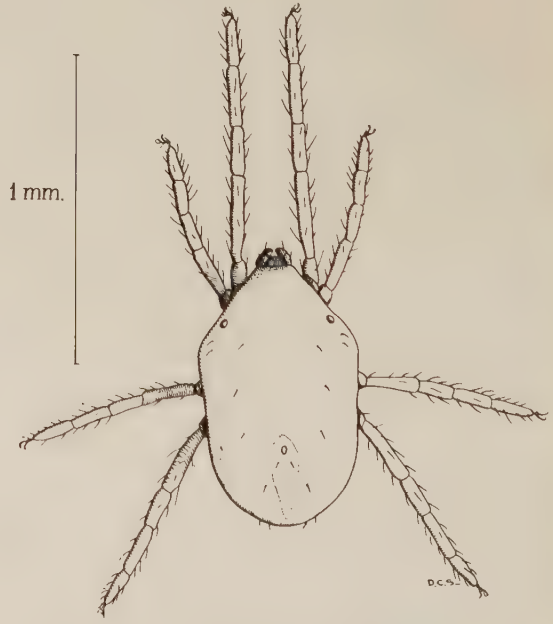
The results of the investigations on the lucerne flea have been discussed in detail in various publications which are listed on pages 107-109.

(2) *The Red-legged Earth Mites.*

Halotydaeus destructor Tucker and *Penthaleus bicolor* Froggatt (Family Eupodidae) have been found to occur widely in the agricultural areas of South Australia. They are known in South Africa (probably their country of origin) and Western Australia as pests of many market crops and some pasture plants.



Red-legged earth mite *(Halotydaeus destructor)*.



Red-legged earth mite *(Penthaleus bicolor)*.

Local outbreaks have occurred in South Australia for some years past, but it was not until the winter of 1933 that they assumed general importance. During this period tomatoes in glasshouses and leguminous crops, such as peas, suffered considerable damage on the Adelaide plains, though most cultivated annuals were to some extent affected. The mites reached their greatest numbers on light soils, but they were quite common on heavy soils, at the Waite Institute in clover pasture and in pea plots, as well as in association with Cape weed (*Cryptostemma calendulaceum*), its favourite food plant. In the South-East of this State it was prevalent, and attacked field peas in the Bordertown-Naracoorte region, as well as home gardens and nurseries.

Subterranean clover damaged by the red-legged earth mite *(Halotydaeus destructor)*.

A study is being made of the various factors affecting their increase in numbers. The biology of *Halotydaeus destructor,* which is the commoner and more destructive species, shows that this mite has a lower temperature optimum than *Smynthurus viridis.* Thus the eggs of *Halotydaeus* at 15°C. (59°F.) hatch in 6 days, whereas those of *Smynthurus* take 16 days. These studies also indicate that the eggs are very sensitive to exposure to unsuitable moisture conditions, and in unfavourable (too wet) conditions a high mortality in the developing egg results.

Best conditions appear to obtain at the surface of light soils, which may explain the abundance of this mite on such soils and its comparative scarcity on

heavy soils. The number of eggs laid by a single mite is not known exactly, but is at least fifty, and this, together with the short incubation period, allows for rapid increase in numbers in suitable weather. Eggs are laid among weeds, and cleanly cultivated areas may be invaded from these. This shows that the removal of weeds near market crops is desirable. The mites feed by piercing the leaves and sucking the sap. Leaves after attack show silvery patches where the mites have fed, due to the presence of a layer of air beneath the epidermis. The assimilatory areas are often considerably affected, and this, together with the water-loss sustained, may result in wilting of the plant, and death where the damage is extensive. Prolonged less severe attack results in greatly stunted growth

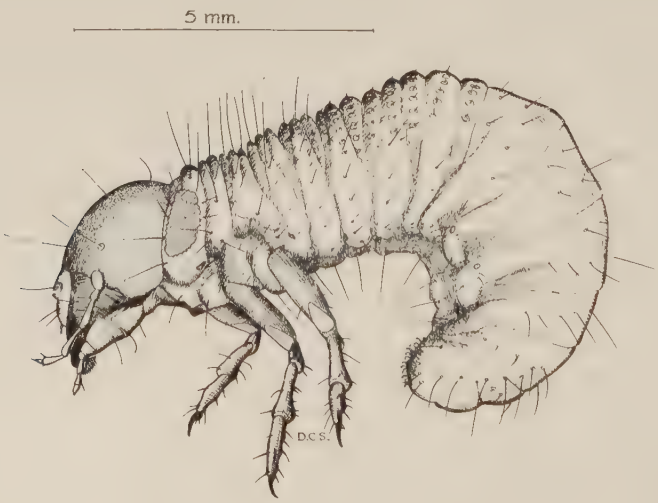
The mites pass the summer in the egg stage, and resemble *Smynthurus* in that they appear after the onset of the autumn rains in April or May, and die out again in early summer. Their activity ceases by early October, and only a few individuals survive into November in favourable local situations, the time of their disappearance again closely following that of *Smynthurus*.

With regard to infestation of many seed-beds, it is evident that clean cultivation of surrounding areas is essential. The mites inhabit the dense growth of weeds, etc., surrounding the cultivated plots, the moisture being favourable. They emerge at night, or on dull days, and attack the seedlings.

Peas are frequently heavily attacked, also lucerne. Where possible an autumn and early winter fallow will clear the area, as in the case of the lucerne flea.

(3) *Cockchafer Grubs.*

With the development of subterranean clover on top-dressed pastures in the South-East, resulting in heavier stocking and manuring, the larvae of certain species of scarab beetles have increased in serious numbers during the past few



Larva of Scareb beetle (*Aphodius* sp.).

years. In particular, the damage caused by the grubs of an *Aphodius* sp. in local situations is very great. These grubs become active with the first autumn rains. They make a vertical burrow in the pasture, emerge at night, and bite off seedling grasses and clovers; at the same time they cover the ground with the soil brought up from the burrows, so that the young growth is smothered. In some places as many as 150 grubs were found in an area of one square foot to a depth of 6 inches. The grubs appear to have a two-year cycle, and the adult beetles emerge in early summer. Treatment of infested areas with lead arsenate sprays has checked the pest in local areas.

(4) *Eelworms.*

Cereal crops in this State are not subject to loss by any major entomological problem, although minor troubles, such as "white grubs" and "cut worms" arise from time to time.

During 1929-1930 a preliminary investigation was carried out on the occurrence of eelworms (*Heterodera schachtii* Schm.) as a pest of cereals. The results of this work were published in 1930.

It was found that the pest was widely distributed, and in the mallee areas particularly it causes reduction in yield. The poor growth of the crop in affected areas appears to be associated with particular soil conditions affecting the growth. With favourable growth conditions and vigorous development of new roots the plants are able to make progress against the attack. Therefore the loss due to eelworm attack is greater in some seasons than in others, depending upon the influence of seasonal conditions on the general growth of the plants. A rotation system, whereby crops may be grown which are not favourable for the eelworms, appears to be a promising line in checking the losses due to this pest. Owing to climatic features, however, the extent to which rotation can be practised in South Australia is greatly restricted.

2. Insect Problems of Orchard and Market Garden Crops.

(1) *Thrips on Tomatoes.*

Investigations on the virus disease of tomatoes known as "spotted wilt", carried out in the Department of Plant Pathology, showed that this disease could be transmitted by a species of thrips which commonly occurs on tomatoes in the Adelaide district.

The species was determined by Dr. G. D. Morison as *Frankliniella insularis* Franklin, originally described from the West Indies. A study of the biology of this species under the climatic conditions obtaining in South Australia was therefore carried out during 1929. The results of this investigation have been published (Publication 118).

The eggs are laid in the tissues of the tomato leaf, and the larvae feed on the leaves or in the flowers; when they are fully fed they pupate in curled leaves or

debris on the soil surface. The species occurs in numerous plants during the summer months, particularly carnations.

The duration of the egg stage varied from 9–14 days with a mean daily temperature of 64·5°F.; the larval stages took from 9–13 days with a mean daily temperature about 66°F., and the pupal stages from 7–14 days with a temperature varying from 72°F. to 63°F. The complete life-cycle with experiments in the glasshouse occupied 36–39 days when the mean daily temperature was about 66°F.

It was shown that the female of this species reproduces without being fertilized, but the offspring from unfertilized eggs consist only of males. Females which have been mated produce eggs some of which develop into males and some into female individuals. This is of interest in relation to the abundance of the species. With many species of thrips which occur in epidemic numbers, the eggs from unfertilized females develop only into females. In this way dense populations may occur when conditions are favourable. It is not known how the species in the West Indies behaves in this respect. Considering the dryness of the summer months in South Australia, compared with humid conditions in the West Indies, it is possible that the species in South Australia is different from that in the West Indies. It would be expected that the summer rainfall area along the coast of New South Wales and Queensland would be more favourable for a species originating in the West Indies. *F. insularis*, however, does not appear to be present in these regions.

Observations on experiments relating to the ratio of males and females in population of the species in Adelaide have been published.

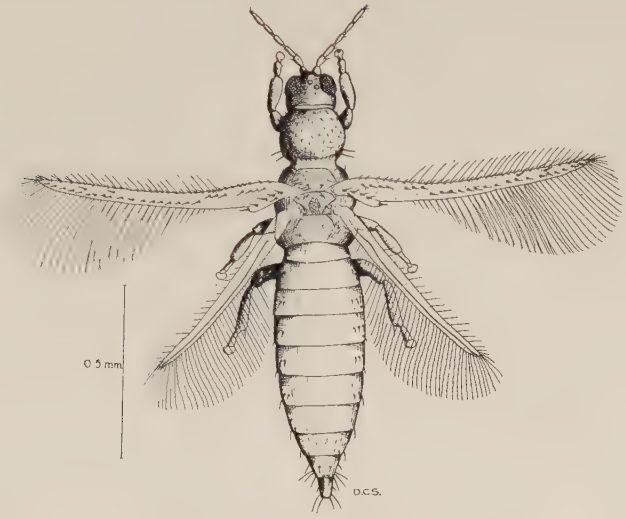
(2) *The Apple Thrips* (*Thrips imaginis* Bagnall).

Widespread thrips infestations have been recorded in the southern States of Australia at intervals during the past twenty-five years, although definite records are not available for South Australia. However, a plague of thrips occurred in the spring of 1931, which was also general in the southern States. An epidemic of these insects also occurred in 1926. The species concerned is *Thrips imaginis*, which was described by Bagnall in 1926 (Ann. Mag. Nat. Hist. *18*: p. 98). It is native to Australia, and its widespread occurrence is associated with agricultural development, resulting in the increase in flowering weeds, garden plants, and orchard blossom.

The species lives in the flowers of many plants, and when it occurs in large numbers in October, during the period of the apple blossom, it seriously affects the setting of fruit.

Owing to the serious losses in the apple crop and bush fruits attributed to thrips, an investigation of the problem was commenced in 1932, under a co-operative arrangement with the Council for Scientific and Industrial Research, the Waite Agricultural Research Institute, the Thrips Investigation League, and

certain of the State Departments of Agriculture. The head of the Department of Entomology is in charge of the investigation, which is centred at the Waite Institute, and a unit of workers is located in the School of Agriculture of the University of Melbourne. Mr. J. W. Evans, an officer of the Council for Scientific and Industrial Research, has been attached to the Entomological Department at the Waite Institute in connection with the investigations.



The apple thrips *(Thrips imaginis).*

The programme consists of an investigation of the apple thrips (*Thrips imaginis* Bagnall) and associated species of blossom and flower thrips, particularly with reference to their economic importance in relation to orchard and bush fruits.

Daily records have been made throughout the year of the numbers of thrips present in flowers and blossoms in the Adelaide district. Similar observations are being made in Victoria. *T. imaginis* occurs throughout the year in South Australia, and the periods of marked increase in the population is dependent on weather factors. The results of these observations have been published (Publication 122). From an analysis of the thrips population from month to month, in association with the meteorological conditions, it appears that it may be possible each year to predict before the spring months whether an outbreak of thrips may be expected. It was possible from the information available by August, 1933, to forecast that there would not be a plague of thrips in the spring of 1933. This prediction proved to be correct.

The presence of thrips in large numbers in the flowers of weeds, etc., such as "Cape Weed", "Salvation Jane", etc., show that they multiply freely outside

the orchard areas. They emerge during the warm spring days and invade the orchards, particularly when the blossom period coincides with spells of hot days having a shade temperature about 77°F. or over.

The practical solution of the problem in relation to apple blossom appears to lie in the development of suitable insecticidal dusts which will protect the blossoms during the critical periods. In general these periods consist of spells of hot days in October. Preliminary tests with dusts containing pyrethrum and also derris have given encouraging results. The present position regarding the progress of the investigation has been discussed elsewhere (Publication 120).

(3) *The Green Peach Aphis* (*Myzus persicae* Sulzer).

The green peach aphis is troublesome on peach and allied fruit trees in spring during certain years. In the spring of 1928 the species occurred in epidemic numbers and caused considerable damage. The life-history of this insect is well known, and observations have been made during the past four years on its behaviour in South Australia. The winged migrants leave the peach trees in late spring, and reproduce throughout the summer on various weeds and garden plants. Winged re-migrants return to the peach tree about April or May, according to the district, and produce the sexual females which lay the winter eggs in the axils of the buds. The number of eggs found on the trees in different districts varies considerably. In one district in June, 1933, the number was 3·18 eggs per twig (about 10 inches long) on 100 twigs. In another district only isolated eggs were present. Observations show that the eggs hatch freely during the winter months. Therefore, when the buds are about to burst in spring most of the eggs may have hatched. The young aphides from the early hatching appear to be destroyed by rain and weather. This is important in relation to the economic importance of the species.

The damage to the peach tree in spring is due to the young aphides, which hatch from the eggs about the time that the buds begin to open. They enter the developing buds and reproduce young aphides in them. These insects suck out the sap from the delicate tissues of the young leaves. This causes the leaves to curl and become severely distorted.

It would appear that certain combination of weather conditions in autumn, winter, and spring result in a larger number of eggs remaining non-hatched until the spring. In these years a heavy infestation of the spring growth occurs, such as obtained in the spring of 1928.

Treatment of affected trees in spring, when the damage is first noted, is not very satisfactory; the insects multiply rapidly, and it is difficult to spray the distorted leaves effectively.

The use of tar distillate washes as winter sprays for aphis eggs was referred to the Department of Agriculture in 1930, and experiments carried out by the Horticultural Department have demonstrated the value of these sprays

for the control of this aphis. It is evident, however, that the expense of winter spraying may not be justified every year in all districts.

It would appear that, with the South Australian climate the winter egg state is indefinite. Observations are being continued, since it appears probable that the years in which severe epidemics may be expected can be determined before the spring period. By this means growers could be advised regarding preventive measures.

The behaviour of this species in relation to weather conditions, as was also demonstrated in the case of the apple thrips, shows the importance of studies relating to meteorological conditions and population increase with economic insects.

(4) *Rind Markings of Oranges.*

It was generally considered by growers that thrips were important agents causing surface blemishes on oranges. These blemishes do not affect the quality of the fruit, but they affect its appearance and grading. The losses owing to the large proportion of inferior grade oranges may be considerable in certain years. An investigation of this problem showed that certain insects are responsible for a small percentage of rind-markings. The greater portion of the blemishes observed during the season 1931-1932 were shown to be due to mechanical injuries to the fruit in earlier stages, caused by wind; a number of blemishes were also due to oleocellosis.

The results of the investigation illustrate the necessity of making a systematic study in order definitely to establish the nature of the problem. An account of this work is given elsewhere (Publication 119).

3. Miscellaneous Investigations.

(1) *Effect of Climate and Weather on Insect Abundance.*

Climate and weather are major factors affecting the seasonal occurrenc and increase in the population of insects. The characteristic features of th climate of South Australia are winter rainfall and summer dryness. This important, particularly in relation to insects inhabiting the soil. Owing to th extreme dryness during November to April it is necessary that these insects aestivate or pass to deeper layers of the soil where moisture is favourable. This has a bearing on the ability of introduced species to survive the dry season. The northern distribution of established species is determined by rainfall, which decreases in amount and regularity with increase in distance from the coast. In the case of insects other than those inhabiting the soil, the high saturation deficiency of the air during the summer months is important, since many species may not be able to make up loss of body water from the food or other sources of water intake. Their occurrence during these periods will be restricted to situations where the local climate is more favourable. From an

analysis of the meteorological data for stations in South Australia the State has been mapped out into districts in which the average moisture and temperature conditions each month have been defined. The information acquired has been used to interpret the possible distribution of the "lucerne flea" over the State, and its seasonal occurrence. It will be applied in a similar manner to the behaviour of certain other species of economic insects.

(2) *Blowflies.*

Blowflies are to be considered as one of the most serious pests of the Commonwealth. Hitherto there was practically no information on record regarding the species present in South Australia. A series of trapping experiments were carried out at the Waite Institute for a complete year, during 1932-1933. The aim was to show which species were present and their relative abundance during each month of the year.

It was found that three species of primary flies, associated with "fly strike" in sheep, are present. These are the European green blowfly (*Lucilia sericata* Meigen), the large brown blowfly (*Calliphora stygia* Fab.), and the less brown blowfly (*Calliphora nociva* Hardy). Two important species of secondary flies are also present, namely, the hairy maggot fly (*Chrysomyia rufifacies* Macquart) and the small metallic-green blowfly (*Microcalliphora varipes* Macquart).

The flies occur more particularly round the sheep-yards or other situations where sheep congregate. *C. stygia* is more abundant during the spring months, while *C. nociva* occurs a little later, extending into the early summer months. *L. sericata* is more abundant in the early summer months. Of the two secondary flies the hairy maggot fly is abundant from late spring to autumn. It is the commonest species. *M. varipes* occurs in greatest numbers in late summer and autumn (Publication 129).

Plant Pathology

The work carried out on plant pathology comprises both advisory and research work. The advisory work involves reporting on specimens of plant diseases submitted through the Department of Agriculture, by farmers, orchardists, and others. During the course of this work records of new diseases are made, together with notes on the prevalence of diseases in South Australia. These are published biennially in the Journal of Agriculture (Publications 94, 100). The research work has been concentrated on three diseases: manganese deficiency of oats and barley, take-all and foot-rot diseases of wheat, and spotted wilt of tomatoes. The work accomplished on each of these is described in greater detail below.

In addition, special work has been done on certain other problems. In 1928-29 a survey was made of the diseases affecting glasshouse tomatoes in South Australia, and the results were written up, together with instructions for control, in a bulletin which has had a wide circulation among tomato-growers (Publication 92).

In 1931 an investigation was made of a disease of cereals which is frequently called "no-growth disease" in the mallee areas. Although it usually occurs only in small patches a few feet across, stunting and killing the seedlings in the early stages, it occasionally affects larger areas up to an acre or more in extent. The disease was shown to be due to the fungus *Rhizoctonia solani,* which attacks the roots, killing them back to brown stubs (Publication 99).

In 1932 an investigation was made of the "big bud" disease of tomatoes, which makes the flowers of tomato plants go "blind", and the fruit which has already set become tough and woody. The disease was shown to be due to a virus, transmissible by budding and grafting, but the insect vector responsible for transmission in the field was not determined (Publication 106).

In 1933 work was commenced on a die-back of apricot limbs which is troublesome in a number of Lower Northern apricot orchards. The disease was found to be due to a fungus which gains entrance to the wood through pruning wounds. The fungus was obtained in culture, but did not fruit until October, 1933, so that no identification was possible at first. The conidial stage now appears to be a species of *Cytosporina,* and a preliminary report is being prepared.

The effect of various rotations and manurial treatments on the severity of the eelworm disease of wheat, due to the nematode *Heterodera schachtii,* was also examined in one of the Waite Institute fields in 1933. It was found that the disease was bad on all wheat crops sown on cereal stubbles, but that it was of minor importance where the crop followed fallow or peas. The results obtained in this survey are also being prepared for publication.

1. Manganese Deficiency.

This was the first problem undertaken by the plant pathology department, and the co-operation of the chemical laboratory and also of the Department of Agriculture for field tests was obtained. For many years a disease of oats had been known on certain soils in the South-East of this State, without the cause of the trouble having been determined. The disease occurred mainly on the volcanic soils around Mount Gambier and Mount Schank, and on certain black clay soils near Penola. The oats would germinate well, but at the time when they should be commencing to tiller the leaves would begin to shrivel up, and large patches in the crops would die completely. It had been suggested at various times that the disease was due to eelworms, to bacteria, or to other causes, but none of the explanations proved satisfactory. When the Waite Institute commenced in 1925 the investigation of this disease was suggested by the Director of Agriculture as being a problem of long standing on which his department would be glad of definite information.

Preliminary experiments showed that it was not an infectious disease, for oats growing in red clay-loam soils could never be induced to get the disease by inoculation from diseased plants. It was also found that when Mount Gambier soil was sterilized with steam the trouble was completely cured; when it was sterilized with formalin, however, the disease was not cured at all. These results suggested that the trouble was some chemical one in the soil, and not due to any disease-producing organism. This quickly led to identification of the disease with the grey speck of oats, known in northern European countries, for which it had recently been found that dressings of manganese salts were beneficial. Tests on Mount Gambier and Penola soil showed that manganese sulphate would completely cure the disease if applied in heavy enough dressings (Publication 31).

In order to understand the disease better pot and water-culture experiments were conducted at the Waite Institute. These showed that when oats were grown in solutions perfectly free from manganese they developed exactly the same symptoms as occurred in the field at Mount Gambier. An addition to the water-culture solution of one part of manganese in five million parts of solution was sufficient to prevent the disease entirely. It was also found that the disease was made worse by liming the soil, and slightly lessened by such manures as sulphate of ammonia. Chemical analyses of healthy and diseased oat plants showed that the former always contained much more manganese than the latter. The evidence combined to show, therefore, that the oat disease was due to a deficiency of available manganese in the soil, and that it could be cured by dressings of soluble manganese salts.

Since pasture plants and weeds grew well on land which would not grow oats, it was of interest to determine whether manganese was also necessary for these plants, and, if so, whether it was that they required much smaller quan-

tities for normal development than the cereals, or whether they were able to absorb more of what manganese was present than could the cereals. Experiments with 10 varieties of cereals, 4 species of grasses, 5 species of legumes, and tomatoes showed that small traces of manganese were essential for the normal growth of all these plants, but that some could grow to maturity with much smaller quantities than others (Publication 32). For example, rye developed to maturity in water-cultures on an amount of manganese which did not allow oats to form any heads even. It is of interest in this connection that when oats were sown at Mount Gambier, on land which is not too susceptible to the disease, a strip of rye is often sown alongside the road, because the alkaline dust blowing off the limestone road always makes the oat disease worst along the fence.

Strip of rye grown along the edge of an oat crop at Mount Gambier to avoid heavy loss due to manganese deficiency.

Factors which influence the availability of manganese in affected soils were further investigated by Mr. C. S. Piper in 1930 (Publication 35). It was known that the manganese deficiency disease of oats was worse in dry years than in wet years; also if a heavy cart had gone across an affected paddock it was always noticeable that the oats grew much better in the track of the cart wheels. Experiments showed that water-logging Mount Gambier soil, or keeping it at 90 per cent. saturation, would make enough manganese available to grow healthy oats. Chemical analyses proved that the oats grown under such conditions had actu-

ally absorbed more manganese. The explanation is that manganese becomes unavailable under conditions of high oxidation, and that water-logging leads to the establishment of reducing conditions in the soil, thus making more of the element available in a soluble form. This would explain why dry years make the disease worse and wet years mitigate it to some extent. Similarly, the influence of soil reaction was investigated, and the increased solubility of manganese under acid conditions and increased crop growth in acid-treated soils proved.

Effect of manganese on barley at Corny Point: left, no manganese; right, 14 lb. manganese sulphate per acre.

(From R. C. Scott, Jrn. Agric., Sth. Aust., Feb., 1932.)

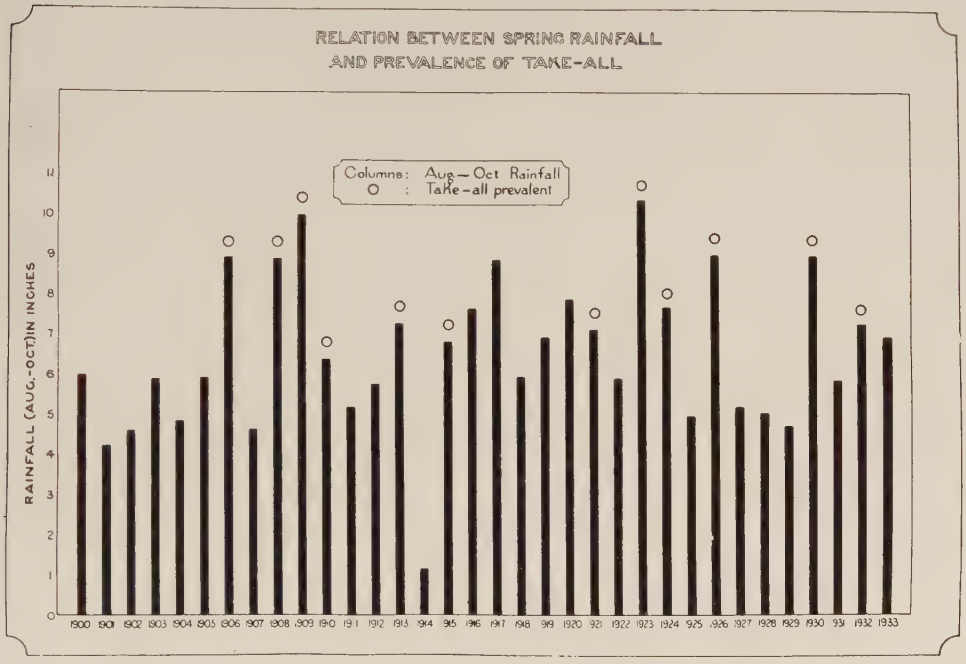
Later it was found that barley grown on certain light, calcareous soils at the foot of Yorke Peninsula became seriously affected with manganese deficiency disease. Field experiments were laid down by the Department of Agriculture, and it was proved that applications of manganese sulphate as small as 14 lb. per acre, sown with the seed, were sufficient to counteract the disease considerably (Scott, R. C., Jour. Agric. Sth. Aust. *35* : 771. Feb., 1932). A mixture containing about 160 lb. of superphosphate and 28 lb. of manganese sulphate is now supplied by fertilizer firms, and is being used to an increasing extent by farmers growing barley on the calcareous soils at the foot of Yorke Peninsula.

2. Take-all of Wheat.

Take-all of wheat is the disease which causes by far the largest economic losses in South Australia. On the lighter soils of the mallee areas it takes a toll of

the crops to some extent every year, and in epidemic seasons it may be responsible for losses running into some millions of bushels.

Several fungi have been shown to be associated with foot- and root-rot diseases of wheat, but examination of many specimens from all over South Australia has proved that the true take-all fungus, *Ophiobolus graminis*, is the one responsible for practically all the losses in this State. Occasional instances of damage by *Helminthosporium sativum* in the northern districts, and by *Fusarium culmorum* mostly in the southern districts, have been recorded.

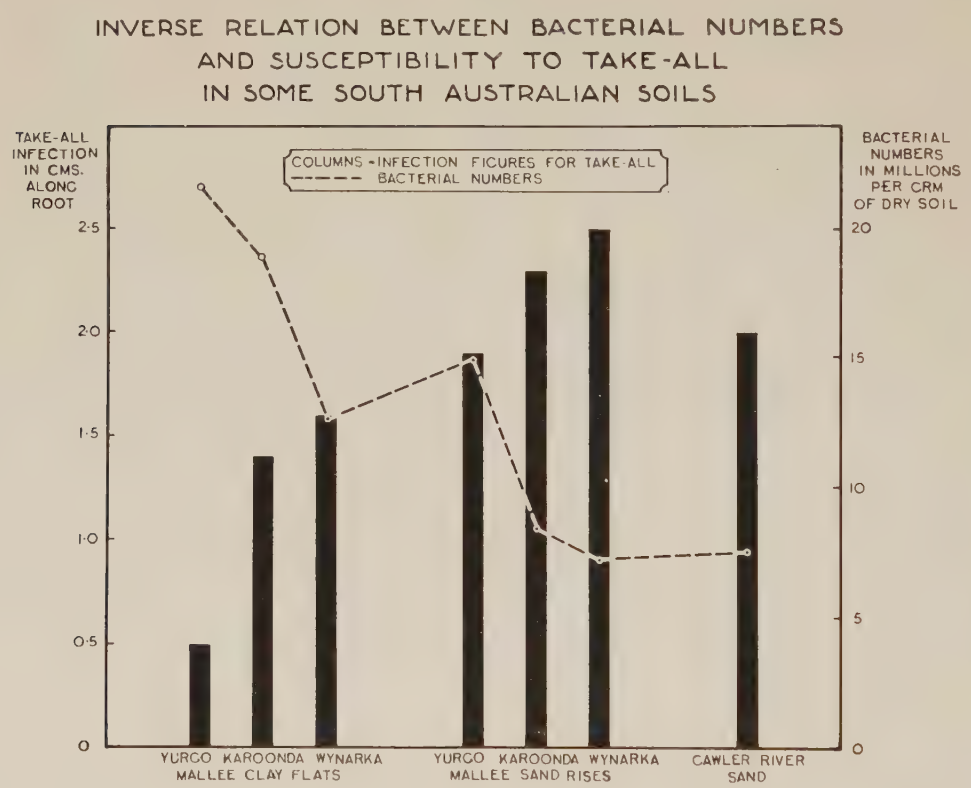


Graph showing relation between spring rainfall and prevalence of take-all.

Attention has therefore been devoted mainly to the take-all disease caused by *Ophiobolus graminis*. The disease appears in two forms: (1) as patches, which may appear early or late, and (2) as scattered plants bleaching off white throughout the crop, often so thickly as to render the crop worthless for stripping. The latter form of take-all occurs only in epidemic seasons, and is the one which causes the greatest losses.

Until recently take-all was considered to be almost entirely a soil disease. It was discovered in 1932, however, that in certain seasons the spore cases of the fungus ripened on diseased plants in early take-all patches by September or October, and that in rainy weather the spores were shot out into the air and blown about in thousands (Publication 107). This would mean that in seasons when the

spring weather was wet and showery take-all spores might be carried down in the rain over large wheat crops, which contained perhaps only a few early patches of the disease in which the fungus was fruiting. It seems likely that in sandy soils the spores would soon be washed down and infect the roots of healthy wheat plants. This would explain the scattered occurrence of infected



Graph showing inverse relation between bacterial numbers and susceptibility to take-all.

plants throughout the crops, and the late appearance of the disease in the white-head stage, as contrasted with its early appearance in the patch form. However, it has still to be proved that ascospore infection of plants almost at the flowering stage may occur. A study of past records reveals that take-all has been most prevalent in years in which the spring rainfall has been above the average, which provides supporting evidence. Fuller discussions of the theory of secondary infection by wind-disseminated ascospores are given elsewhere (Publications 101, 107).

Another important factor influencing the development of take-all is the population of other micro-organisms in the soil (Publication 101). It has been

shown that certain soil bacteria exercise a strong antagonistic effect to the growth of the take-all fungus. It is apparently the larger numbers and to some extent the different kinds, of soil bacteria in the more fertile soils which make take-all so much less of a problem in the well-established wheat-growing districts of the northern areas than it is on the light soils of the mallee. The results of some laboratory tests with mallee soils are shown in the accompanying graph. It is seen that the rate of growth of the take-all fungus down wheat roots was much greater in the sandhill soils than in the soils from clay flats, whereas bacterial numbers varied in the inverse direction.

It has been known for some time that newly-opened areas in the mallee districts suffer rather severely from take-all in the early stages, but that after some twenty years of cultivation the disease becomes less to be feared. It seems probable that the explanation of this is that continued cultivation gradually increases the organic matter content and the bacterial flora of the soil, and the antagonistic effect of the soil bacteria provides an increasing natural check on the growth of the take-all fungus. Practices such as the growth of early-maturing legumes in the rotation, and the carrying of more sheep, should therefore be of considerable importance in any programme for the control of take-all on light soils.

3. Tomato Spotted Wilt.

The investigation of tomato spotted wilt was commenced in 1926, in co-operation with the Commonwealth Council for Scientific and Industrial Research. The Council provided an insect-proof glasshouse for the experimental work and the salary of an assistant investigator and expenses.

Tests with various species of insects proved that the disease was spread in the field only by two species of thrips, the black carnation thrips, *Frankliniella insularis*, and the onion thrips, *Thrips tabaci* (Publications 88, 93, 97). It was found that the insects only became infective by feeding on a diseased plant in the larval stage, but that, once infected, they retained the infection through pupation and throughout their adult life (Publications 96, 97). A very short period of feeding on a healthy plant is sufficient for inoculation of the virus to occur.

After a plant has been inoculated by an infective thrips there is an incubation period of about twelve days before the bronzing symptoms of wilt appear on the top leaves. Plants infected when they are young become worthless for further fruit-bearing; plants infected when they are already bearing fruit have much of the fruit spoilt by unsightly yellow blotching.

A study by Mr. J. G. Bald of the distribution of infected plants in field plots showed that the insect vectors of the disease are extremely active. They are on the move mainly at temperatures over 80°F., and are likely to land on plants quite at random.

The disease has a very wide host range, having been recorded on 55 plants in

nine different families. Unfortunately common garden plants, such as Iceland poppies, nasturtiums, zinnias, dahlias and others are susceptible, and these undoubtedly provide one of the main methods of over-wintering of the virus (Publication 96). It is for this reason that spotted wilt is a more serious trouble in suburban gardens than it is in isolated places in the country. Occasionally tobacco fields are seriously affected (Publication 104).

Attempts at control by the ordinary insecticidal dusts have given poor results. The first infections in a plot of young plants put out in October or November probably come from wandering *Thrips tabaci* which have hatched on some infected garden plant or weed. Experiments are being made with some of the repellent dusts containing pyrethrum which are being developed by the workers of the Thrips Investigation, in an effort to keep off this early source of infection. Later spread of the disease in a plot will also occur from thrips which hatch on diseased plants, so that prompt removal of diseased plants should become a regular practice. *Frankliniella insularis*, which is a thrips with a warmer temperature optimum than *Thrips tabaci*, becomes the main vector during the summer months.

The small currant tomato, *Lycopersicum pimpinellifolium*, showed a marked resistance to spotted wilt in field tests, so in 1928 crosses were made between it and commercial varieties in an effort to breed a variety of tomato possessing some resistance to spotted wilt. Unfortunately it was found that all the undesirable characters of the currant tomato were dominant, and that the inheritance of characters in this cross was particularly complicated. No segregates with commercial fruit size were obtained from growing some 3,000 second-generation plants.

It is possible that further progress might be made in the future if a method of testing seedlings for resistance to spotted wilt in the seedling stage was available. Some attention has therefore been given to developing methods of mechanical inoculation (Publications 95, 103, 105).

At present the best methods for control involve growing tomatoes as far as possible from garden plants and weeds, using a repellent dust just before hot north winds, and removing diseased plants at least once a week.

Waite Arboretum

Under the deed of gift of the late Mr. Peter Waite, whereby the Urrbrae estate was transferred to the University, it was provided that portion of the area containing 67 acres, should be held by the University in perpetuity as a park. It was further provided that the Council of the University may set apart a portion, not exceeding 15 acres, for the purposes of a sports ground, to be used by the graduates, undergraduates, and other students of the University, subject to such regulations as the Council of the University may prescribe.

To give effect to this the University Council decided that the best means of carrying out the terms of the gift would be to establish on this area an arboretum, in which trees and shrubs should be grown as specimen trees to demonstrate their value for shelter and ornamental purposes.

On this area 1,020 trees have been planted, comprising 67 families, 180 genera, and 367 species, in accordance with the accompanying plan.

The arboretum comprises two main sections, one devoted exclusively to indigenous species and the other to introduced species.

The classified list of trees and shrubs is as follows:

A. Gymnospermae.

Ginkgoaceae

Ginkgo biloba

Podocarpaceae

Podocarpus amara, elata, elongata, spinulosa, Totara

Araucariaceae

Araucaria Bidwillii, Cunninghamii, excelsa

Agathis robusta

Pinaceae

Abies pectinata

Picea Albertiana, pungens var.

Cedrus atlantica var., *Deodora, Libani*

Pinus canariensis, halepensis, Pinaster, ponderosa, radiata, Taeda

Taxodiaceae

Sequoia gigantea, sempervirens

Taxodium distichum

Crytomeria japonica var.

Cunninghamia sinensis

Cupressaceae

Callitris cupressiformis, Macleayana, oblonga, robusta

Widdringtonia cupressoides

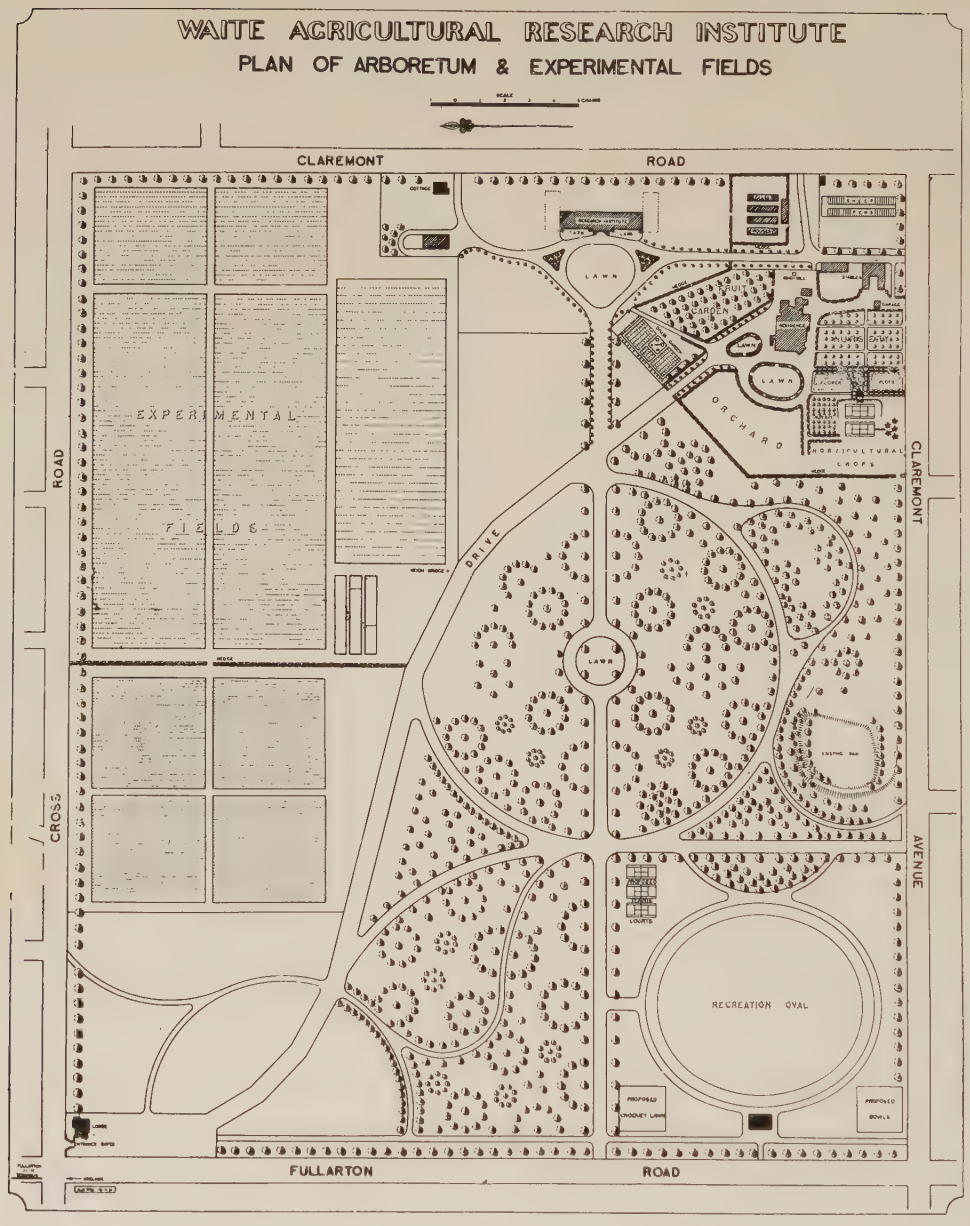
Thuja occidentalis, orientalis var., *plicata*

Libocedrus decurrens

Cupressus arizonica, funebris, glabra, Goveniana, lusitanica and var., *Macnabiana, macrocarpa* var., *sempervirens* and var., *torulosa*

Chamaecyparis Lawsoniana, nootkatensis, pisifera var., *thyoides* var.

Juniperus bermudiana, chinensis, communis var., *procera, virginiana*



Plan of arboretum and portion of experimental fields. Waite Institute.

B. Angiospermae.

Class 1. Monocotyledoneae.

Palmae

Phoenix canariensis, dactylifera, reclinata, sylvestris
Trachycarpus excelsa, humilis
Livistona australis, chinensis
Pritchardia robusta
Washingtonia filifera
Sabal Blackburnianum
Erythea armata
Ptychosperma elegans
Arecastrum Romanzoffianum
Jubea spectabilis
Diplothemium campestre, maritimum

Liliaceae

Cordyline australis, terminalis
Dracaena Draco

Amaryllidaceae

Doryanthes Larkinii

Class 2. Dicotyledoneae.

Subclass Archichlamydeae

Casuarinaceae

Casuarina Cunninghamiana sumatrana, torulosa

Salicaceae

Populus alba and var., *monilifera, nigra* and var., *serotina* var., *tremula*
Salix babylonica, caprea, purpurea

Garryaceae

Garrya elliptica

Juglandaceae

Juglans regia
Carya pecan

Betulaceae

Betula pubescens

Fagaceae

Castanea vesca
Quercus bicolor, cerris, coccinea, Ilex, incana, lusitanica, macrocarpa, Mirbeckii, palustris, pedunculata, phillyraeoides, suber, virginiana
var. *parvifolia, pumila, sube-*

Ulmaceae

Ulmus americana and var., *campestris, foliacea, hollandica rosa*
Celtis australis

Moraceae

Maclura aurantiaca
Ficus Benjamina Hillii, macrophylla, rubiginosa, scabra

Proteaceae

Protea mellifera
Macadamia ternifolia
Grevillea Banksii var., *Hilliana, robusta*
Hakea elliptica, laurina, pubescens, saligna, suaveolens
Lomatia silaifolia
Stenocarpus salignus, sinuatus
Banksia grandis

Nyctaginaceae

Pisonia inermis

Phytolaccaceae

Phytolacca dioica

BERBERIDACEAE

Berberis aquifolia, Darwinii
Mahonia japonica

MAGNOLIACEAE

Magnolia grandiflora
Liriodendron tulipifera

LAURACEAE

Cinnamomum camphora
Umbellularia californica
Cryptocarya glaucescens, obovata
Laurus nobilis

SAXIFRAGACEAE

Ribes sanguineum

PITTOSPORACEAE

Pittosporum crassifolium, eugenioides, nigrescens, Ralphii, tenuifolium, undulatum
Hymenosporum flavum

HAMAMELIDACEAE

Liquidambar styraciflua

PLATANACEAE

Platanus acerifolia, orientalis, Wrightii

ROSACEAE

Cotoneaster Simonsii
Sorbus Aucuparia
Photinia serrulata
Crataegus oxyacantha and var.
Pyracantha angustifolia, coccinea, crenulata
Prunus cerasifera and var., *lusitanica*

MIMOSACEAE

Pithecolobium pruinosum
Acacia Baileyana, cultriformis, dealbata, decurrens and var., *dodonaeifolia, falcata, floribunda, Greggii, implexa, leprosa, longifolia, melanoxylon, pendula, pruinosa, saligna, Sophorae, stenophylla, suaveolens, terminalis*

CAESALPINIACEAE

Schotia latifolia
Bauhinia purpurea, variegata
Cercis siliquastrum
Cassia artemisioides, Brewsteri, didymobotrya
Ceratonia siliqua
Gleditschia japonica, triacanthos

PAPILIONACEAE

Castanospermum australe
Sophora japonica, secundiflora
Virgilia capensis
Podalyria calyptrata
Crotalaria Cunninghamii
Laburnum vulgare var.
Anthyllis Barba-Jovis
Robinia Kelseyi, Pseudacacia and var.
Caragana arborescens
Erythrina caffra, Coralloden-dron, Crista-galli, Humeana, indica, speciosa

RUTACEAE

Choisya ternata
Calodendron capensis
Flindersia australis

SIMARUBACEAE

Ailanthus glandulosa

MELIACEAE

Cedrela australis
Melia azedarach
Dysoxylum Fraseranum
Owenia venosa

EUPHORBIACEAE

Glochidion Ferdinandii
Mallotus japonicus
Baloghia lucida
Sapium sebiferum

ANACARDIACEAE

Pleiogynium Solandri
Harpephyllum caffrum
Pistacia chinensis
Schinum terebinthifolius
Rhus succedanea

CORYNOCARPACEAE

Corynocarpus laevigatus

AQUIFOLIACEAE

Ilex Aquifolium, Cassine

CELASTRACEAE

Euonymus japonicus and var., *radicans* var.
Elaeodendron australe

ACERACEAE

Acer Negundo and var., *Pseudo-Platanus*

HIPPOCASTANACEAE

Aesculus Hippocastanum

SAPINDACEAE

Alectryon excelsa
Cupaniopsis anacardioides, serrata
Diploglottis Cunninghamii
Elattostachys xylocarpa
Arytera divaricata
Mischocarpus pyriformis
Koelreuteria paniculata
Harpullia pendula

RHAMNACEAE

Ceanothus divaricatus
Alphitonia zizyphoides

ELAEOCARPACEAE

Elaeocarpus obovatus

TILIACEAE

Tilia platyphyllos

MALVACEAE

Lagunaria Patersonii
Hibiscus Rosa-sinensis

STERCULIACEAE

Dombeya Dregeana, Masteri, natalensis
Brachychiton acerifolius, discolor, populneus, populneo-acerifolius, rupestris, trichosiphon

DILLENIACEAE

Hibbertia cuneiformis

TAMARICACEAE

Tamarix gallica, juniperina, pentandra
Myricaria germanica

BIXACEAE

Idesia polycarpa

LYTHRACEAE

Lagerstroemia Flos-reginae, indica

MYRTACEAE

Feijoa Sellowiana
Eugenia Coolminiana, Jambos, Luehmanii, oleosa, paniculata, pendula, pungens, Smithii, Ventenatii
Backhousia citriodora, myrtifolia
Metrosideros tomentosa
Syncarpia glomulifera
Tristania conferta, laurina
Angophora intermedia, subvelutina
Eucalyptus Blaxlandii, Bosistoana, botryoides and var., *calophylla, citriodora, cladocalyx, conglobata, conica, Deanei, diversifolia, elaeophora, erythronema, ficifolia, globulus, gomphocephala, haemastoma, intertexta, microtheca, Muelleriana, ovata, polybractea, punctata, quadrangulata, rostrata, Sideroxylon, Smithii, Stricklandii, terminalis*

Agonis flexuosa
Callistemon citrinus, pallidus, rugulosus, salignus
Melaleuca gibbosa, hypericifolia, macronycha, nesophila, pubescens, styphelioides

ARALIACEAE
Schefflera actinophylla
Oreopanax reticulatum

SUBCLASS METACHLAMYDEAE.

ERICACEAE
Arbutus Unedo

SAPOTACEAE
Sideroxylon argenteum, australe

EBENACEAE
Royena pallens

OLEACEAE
Fraxinus americana, excelsior and var., *Ornus, oxyphylla*
Syringa vulgaris
Ligustrum japonicum

LOGANIACEAE
Buddleia sp.

APOCYNACEAE
Acocanthera spectabilis
Tabernaemontana laurifolia
Ochrosia elliptica, Moorei

VERBENACEAE
Lantana triomphe du commerce
Citharexylum subserratum
Duranta Plumieri
Vitex lucens
Gmelina Leichhardtii
Clerodendron tomentosum

LABIATAE
Prostanthera lasianthos

SOLANACEAE
Solandra guttata
Cestrum purpureum

SCROPHULARIACEAE
Paulownia tomentosa
Veronica Andersonii

BIGNONACEAE
Tecomaria capensis
Jacaranda mimosaefolia
Catalpa bignonioides, speciosa
Stenolobium Stans

MYOPORACEAE
Myoporum acuminatum

RUBIACEAE
Coprosma Baueri, lucida

CAPRIFOLIACEAE
Sambucus nigra
Viburnum Tinus
Abelia chinensis
Lonicera fragrantissima

Total : 67 families, 180 genera, 367 species.

Papers Published by the Staff of the Waite Agricultural Research Institute since its Foundation

I. SOIL INVESTIGATIONS.

(A) Soil Classification.

1. J. A. Prescott. Aust. Ass. Adv. Sci. (Perth) *18*: 724. 1926.
"Soil Classification and Survey."
A discussion of possible bases for a system of soil classification and survey suitable for Australia.

2. J. A. Prescott. Jour. C.S.I.R. *1*: 110. 1927.
"Soil Studies in Australia."
A memorandum prepared for the Imperial Agricultural Research Conference.

3. J. A. Prescott. Jour. C.S.I.R. *1*: 227. 1928.
"An Enquiry into Tasmanian Soil Conditions."
A report, with historical introduction, on the desirability of the systematic examination of the soils of Tasmania from the point of view of fertility level, suitability for specific crops and scientific classification.

4. J. A. Prescott. Trans. Roy. Soc. Sth. Aust. *53*: 7. 1929.
"The Vegetation Map of South Australia."
Two maps illustrating the distribution of certain major vegetation associations in South Australia based on records of the Lands Department supplied by the Surveyor-General.

5. J. A. Prescott. Jour. C.S.I.R. *2*: 112. 1929.
"A Note on the Diagrammatic Representation of the Mechanical Analysis of Soil."
The mechanical composition of soil according to the International Units for Clay, Silt, Fine Sand, and Coarse Sand lends itself admirably to representation by plotting within a tetrahedron. Groups of related soils frequently fall along a plane within the tetrahedron.

6. J. A. Prescott. Jour. C.S.I.R. *3*: 123. 1930.
"A Tentative Soil Map of Australia."
A first attempt at the accurate mapping of the major international soil zones in Australia.

7. J. A. Prescott. C.S.I.R. Bull. 52. 1931.

"The Soils of Australia in Relation to Vegetation and Climate."

An account of the general principles of soil classification based on the study of the soil profile and on the correlation between soil leaching and external climatic factors. The mobility within the profile of water-soluble salts, calcium and magnesium carbonates, oxides of iron, and manganese and clay is discussed. The accession of cyclic salt and the control of leaching by the daily rainfall incidence is shown to be of importance in southern Australia.

The occurrence of laterite in Australia is discussed in relation to its physiographic occurrence as a *duricrust*. The relationship between laterite and the Western Australian sand plains is emphasized, and evidence brought forward to develop the theory that laterite represents a fossil illuvial horizon on an ancient peneplain surface, the sand plains themselves being ancient podsols.

The survey records and ecological literature of Australia have been examined and correlated. Maps of the major vegetation associations and soil zones are present.

The following vegetation associations are recognized: Desert grass (porcupine grass) on sandhills; desert scrub, characterized by acacias, mulga, myall, and gidgea; shrub steppes of saltbush and bluebush; savannahs and Mitchell grass downs; savannah woodlands; mallee scrub and sclerophyll woodlands; brigalow scrub; sclerophyll forests; rain forests; mountain grasslands and high moors; heath and sclerophyll scrub.

The soil groups proposed include: Desert soils and semi-desert soils of sandhills, gibber and gravel plains and stony surfaces; mallee soils, calcareous, somewhat saline, and weakly solonized; red-brown earths, weakly podsolized surface, with calcium carbonate in deeper horizons; black earths, mainly heavy soils in eastern Australia; grey and brown soils, principally heavy soils in the semi-arid zone; podsolized soils in regions of higher rainfall under sclerophyll forests; red loams mainly derived from deeply weathered basalts; high moor; lateritic sand plains, presumed to be ancient podsols.

8. J. A. Prescott. Soil Research *3*: 133. 1933.

"The Soil Zones of Australia."

A summary of existing knowledge relating to the distribution of the major soil zones in Australia. Includes climatic diagram showing relationships of soil zones to rainfall and saturation deficiency, and coloured plate of characteristic profiles.

9. J. A. Prescott, J. K. Taylor, and T. J. Marshall. Trans. Commission I, Intern. Soc. Soil Sci., Vol. A. 1934 (in press).

"The Relationship Between the Mechanical Composition of the Soil and the Estimate of Texture in the Field."

From the experience gained during recent soil surveys in Australia a relationship between estimates of texture in the field and the mechanical composition (international standards) of mineral soils has been established. This relationship has been correlated with the system developed by workers in the United States.

(B) Soil Surveys.

10. E. P. Bainbridge. Jour. C.S.I.R. *1*: 341. 1928.

"Reconnaissance of some Australian Tobacco Soils, with Reference to Reaction and Mechanical Analysis."

Field and laboratory descriptions of soils collected in the tobacco-growing areas of New South Wales, Victoria, and South Australia. Mechanical analyses are plotted and compared with those for American tobacco soils.

11. J. K. Taylor and H. N. England. C.S.I.R. Bull. 42. 1929.

"A Soil Survey of Block E (Renmark) and Ral Ral (Chaffey) Irrigation Areas."

A soil survey of portion of the Renmark Irrigation Area, consisting of a river terrace. Ten soil types are described and mechanical and chemical analyses are recorded.

The productivity of the area is discussed in relation to the significance of a recent flood line (1917), the occurrence of hardpans and wind-swept areas, and the correlation between soil types and crop vigour.

12. J. A. Prescott and C. S. Piper. Trans. Roy. Soc. Sth. Aust. *53*: 196. 1929.

"The Volcanic Soil of Mount Gambier, South Australia."

Mechanical and chemical analyses are given of samples representative of soils on the Pleistocene volcanic ash at Mount Gambier. The soils are slightly acid to alkaline (pH 6·4–8·2), and the nitrogen content ranges from 0·1 per cent. to 0·4 per cent. The P_2O_5 content, up to 0·5 per cent., is unusually high for South Australia. Exchangeable bases are high, showing a satisfactory proportion of calcium.

In texture the soils are grouped as sands, sandy loams and loams.

13. J. A. Prescott. Imperial Fruit Production Conference, 1930.

"Soil Surveys in Relation to Fruit Production in the Murray Valley."

An account of soil survey work and soil investigations in progress in the Murray Valley.

14. J. A. Prescott and J. K. Taylor. Jour. C.S.I.R. *3*: 229. 1930.
"The Value of Aerial Photography in Relation to Soil Surveys and Classification."

Aerial photographic surveys were carried out by the Royal Australian Air Force at Renmark prior to the soil survey. The photographs were of value in recording accurately the type, area and regularity of cropping and for the mapping of associations of native vegetation, which were found to be closely correlated with the soil types.

15. J. K. Taylor and F. Penman. C.S.I.R. Bull. 45. 1930.
"A Soil Survey of the Woorinen Settlement, Swan Hill Irrigation District, Victoria."

A survey of 2,300 acres, carried out in co-operation with the Department of Agriculture of Victoria. Six soil types are recognized and described. Detailed mechanical and chemical analyses are quoted, and the soil types discussed in relation to fertilizer requirements, irrigation, and drainage.

16. J. K. Taylor and H. G. Poole. C.S.I.R. Bull. 51. 1931.
"A Soil Survey of the Swamps of the Lower Murray River."

A survey of 13,000 acres of swamp land along the Lower Murray, between Mannum and Wellington. Two major soil types are recognized and described. The soils are very heavy clays substantially modified by organic matter. High natural water-tables make drainage problems of considerable importance.

Field experiments on liming and on the effects of phosphatic and nitrogenous fertilizers are considered desirable.

17. J. K. Taylor and H. G. Poole. Journ. C.S.I.R. *4*: 83. 1931.
"Report on the Soils of the Bed of Lake Albert, South Australia."

A survey, carried out from a motor launch, of the bed of Lake Albert, comprising 36,000 acres. Three hundred borings were made to a depth of 14 feet by means of a specially designed sampling tool. Seven soil types were recognized on the basis of depth of mud over sand or limestone.

The main characteristics affecting reclamation proved to be:

(1) Extreme heaviness of the soil.
(2) High content of soluble salts.
(3) Only moderate amounts of organic matter.
(4) Neutral to alkaline reaction.
(5) Relative high proportion of exchangeable sodium.
(6) Content of plant nutrients of which potash is high, phosphoric acid moderate, and lime low.

18. T. J. Marshall and P. D. Hooper. C.S.I.R. Bull. 56. 1932.
"A Soil Survey of Blocks A, B, C, D, and F, Renmark Irrigation District, South Australia."

An investigation completing the soil survey of the Renmark settlement. Thirteen soil types are recognized. The area is a complex of river terraces and superimposed sandhills, with adjacent sandhill country.

Mechanical analyses, salt content, and pH values are noted.

Salt accumulation is not generally serious, except under special topographic conditions.

19. J. A. Prescott and J. K. Taylor. Jour. C.S.I.R. *5*: 129. 1932.
"The Nomenclature of Australian Soils."

Sufficient experience in soil surveys has been attained to justify the naming of individual soil types according to the binary system of the United States. Twenty-eight type names are listed.

20. J. K. Taylor and J. O'Donnell. Trans Roy. Soc. Sth. Aust. *56*: 1. 1932.
"The Soils of the Southern Portion of the Hundred of Kuitpo."

An account has been given of the soils, their classification and distribution in the southern half of the Hundred of Kuitpo. The soils are grouped into five series and seven soil types. Mechanical analyses, reactions, and nitrogen content of the soils are tabulated and discussed. The relation of soil types to natural vegetation, to agricultural development, and to reafforestation is briefly noted.

21. C. S. Piper. Trans. Roy. Soc. Sth. Aust. *56*: 15. 1932.
"Some Characteristics of Soils Used for Turf Wickets."

Soils used for the preparation of turf wickets in Australia are heavy black clays. Their principal characteristics are high clay content (56–73 per cent.) and low calcium carbonate.

22. J. A. Prescott and C. S. Piper. Trans. Roy. Soc. Sth. Aust. *56*: 118. 1932.
"The Soils of the South Australian Mallee."

An examination of 328 soil samples from 148 localities in the mallee areas of South Australia. The main characteristic of the mechanical analysis is a low silt content rarely exceeding 10 per cent. Clay content varies from 2 to 60 per cent.

Frequency distribution tables are given for calcium carbonate content, pH values, nitrogen content, and chloride content, and for potash and phosphoric acid in a limited number of soils. The soil reaction is predominantly alkaline.

Potash values are high, phosphoric acid values are low. Replaceable bases show a high proportion of magnesium and frequently a moderate proportion of sodium in the subsoils. The separation of a clay illuvial horizon is attributed to solonization.

Details of analysis are given in the case of nineteen profiles.

23. T. J. Marshall and N. J. King. C.S.I.R. Bull. 62. 1932.
"A Soil Survey of the Cadell Irrigation Area and New Era, South Australia."

A survey of 2,100 acres, of which 950 acres are under horticultural crops. Five soil types are recognized and described. Water-logging and salt accumulations have developed to a serious extent. It is concluded that the salt trouble owes its origin to a rising water-table, combined with the natural occurrence of soil salinity in a valley bottom.

24. C. G. Stephens and J. S. Hosking. C.S.I.R. Bull. 70. 1932.
"A Soil Survey of King Island."

A co-operative investigation with the University of Tasmania. A soil survey of King Island, situated in Bass Strait, has been made. Eight soil types, together with a group of swamp soils, including five well-defined subtypes, have been identified and described. The soil types are individually characterized by a distinctive vegetation association and by topographical situation, and show a considerable degree of uniformity in horizon succession of the profile and in texture.

Chemical and mechanical analyses of soil samples representative of the types have been carried out. Low values for plant foods are associated with many of the soil types, and a high degree of acidity is a feature of three of them. The probable lime requirements of the more acid soils have been ascertained and correlated with losses on ignition and pH values.

The agricultural development of the island, which has been along the lines of livestock fattening and subsequently of dairying, is discussed. Two problems of livestock are associated with the soil formations: the so-called "coastal" disease and a general phosphate deficiency.

25. T. J. Marshall and F. Penman. Jour. C.S.I.R. *5*: 215. 1932.
"A Soil Survey of Part of Murrabit Irrigation Settlement (Victoria) and of the Bungunyah Irrigation Settlement (N.S.W.)."

A survey conducted jointly with the Department of Agriculture of Victoria. Four soil types were identified and described. The soils are principally heavy clays, and comparisons are made between the major type at each settlement and previously described soils of the Murray flats in the Swan Hill district.

26. J. K. Taylor, F. Penman, T. J. Marshall, and G. W. Leeper. C.S.I.R. Bull. 73. 1933.
"A Soil Survey of Nyah, Tresco, Tresco West, Kangaroo Lake (Vic.), and Goodnight (N.S.W.) Settlements."

A co-operative investigation with the University of Melbourne and the Department of Agriculture of Victoria. Soil surveys on five settle-

ments in the Murray Valley, aggregating 9,300 acres, planted to horticultural crops. A proportion of each settlement has been rendered unproductive through soil salinity.

Six soils are defined and fully described. Analytical data for a range of 112 samples are given.

27. Edited by J. K. Taylor. C.S.I.R. Bull. 76. 1933.

"A Soil Survey of the Hundreds of Laffer and Willalooka, South Australia."

A soil survey of an area of 311 square miles in the "Ninety-Mile Desert" of South Australia. Three soil types are named and fully described, namely, Laffer sand (four phases), Willalooka sand (two phases), and Monkoora sand, and additional soils grouped on the basis of elevation, liability to inundation, or vegetation associations.

The soils are very poor in plant nutrients except potash, and require material building up.

The normal and woodland phases of the Laffer sand are the most promising types for exploitation. The Willalooka sand needs further investigation from the point of view of water-logging and scrub regrowth after clearing.

28. J. A. Prescott. Empire Jour. Expt. Agric. (in press).

"Soil Surveys in Australia."

An account of the development since 1907 of the conception of soil surveys for Australia. Systematic work began in 1927. Two independent organizations in the eastern States and in Western Australia have surveyed 2,363 square miles. Methods of survey are described. The correlation of Australian soil types with those elsewhere is discussed.

(c) Soil Fertility.

29. J. A. Prescott and C. S. Piper. Jour. Agric. Sth. Aust. *30*: 738. 1926.

"Synthetic Farmyard Manure."

An account of the preparation of "Adco" synthetic farmyard manure and of a manurial experiment on potatoes conducted therewith.

30. J. A. Prescott. Trans. Roy. Soc. Sth. Aust. *51*: 287. 1927.

"The Reaction of South Australian Soils."

A discussion of the hydrogen ion concentration of South Australian soils. A close relationship is generally noted between rainfall and pH values.

31. G. Samuel and C. S. Piper. Jour. Agric. Sth. Aust. *31*: 696, 789. 1928.
"Grey Speck (Manganese Deficiency) Disease of Oats."

A disease of oats, known to occur on the volcanic soils of Mount Gambier and Mount Schank, and on the black clay soils of drained swamp areas near Penola and Millicent, was shown to be identical with the *Dörrfleckenkrankheit* disease of oats in northern European countries. Pot experiments with Mount Gambier and Penola soils showed that the disease could be prevented by (1) acidification of the soil, (2) partial sterilization of the soil by heat, and (3) applications of manganese sulphate. Water culture experiments, using specially purified salts, showed that in the absence of manganese, oat plants developed symptoms which were identical with those shown by diseased field plants. One part of manganese in four million parts of solution was sufficient to prevent the appearance of the disease in water-cultures. Chemical analyses of healthy and diseased oats showed that the former plants always contained more manganese than the latter. The evidence indicates that the disease is a true deficiency disease, due to unavailability of manganese in affected soils. Field experiments at Mount Gambier confirmed the value of manganese sulphate in controlling the disease. The untreated plots failed completely, whereas applications of manganese sulphate enabled a crop to be grown.

32. G. Samuel and C. S. Piper. Ann. Appl. Biol. *16*: 493. 1929.
"Manganese as an Essential Element for Plant Growth."

In continuation of previous work on the manganese deficiency disease of oats, water-culture experiments were carried out with a number of other plants, with special precautions to ensure the absence of manganese. Three varieties of wheat, four varieties of oats, barley, rye, four species of grass, five legumes, tomatoes, and maize were tested. Manganese was found to be an essential element for the growth of all these plants, becoming necessary at an early seedling stage, and remaining necessary until a late stage in growth. The symptoms of manganese deficiency were found to be essentially an arrest in development, followed by death of the immature tissues at the growing points, together with a certain amount of chlorosis of the upper leaves. Increases in growth from 300 to 5,000 per cent. over that of the manganese-free controls were obtained by the addition of one part of manganese per million parts of solution. None of ten different rarer elements tested, nor the combination of zinc, copper, boron, and aluminium, was able to replace manganese in the growth of oats.

Analyses of diseased and healthy oat plants showed that when the manganese content was less than about 14 parts per million of dry mat-

ter manganese deficiency symptoms were to be expected. On soils with abundant available manganese it was found that considerably more manganese was absorbed than was required for normal development. The amount absorbed was found to vary greatly, and in all probability depends to some extent on soil reaction and soil aeration. There was no evidence that such factors as traces of organic matter, excess of calcium ions, or excess of nitrates play any part in the appearance of the disease in water-cultures containing a soluble manganese salt.

33. J. A. Prescott. Aust. Ass. Adv. Sci., Hobart, 1928, *19*: 566. 1929.
"The Agricultural Significance of Soil Reaction."

An account of the general relationship between the hydrogen ion concentration of the soil, the growth of plants, the occurrence of plant diseases, and the general classification of soil types. Methods available for the correction of soil reaction through the use of lime, sulphur, and gypsum are discussed.

34. J. A. Prescott and G. R. Piper. Jour. Agric. Sci. *20*: 517. 1930.
"Nitrate Fluctuations in a South Australian Soil."

Observations at the Waite Institute from 1925 to 1930 on the fluctuations in the nitrate content of the soil are discussed. The rate of nitrification is governed primarily by soil moisture conditions, and the activity is greatest in the surface layers cultivated during fallowing. Temperature conditions are favourable throughout the year. There is normally no change during the summer drought period.

About 20 parts per million of nitrate nitrogen for the top 18 inches of soil appears to be a normal value for the accumulated nitrate at the beginning of the summer.

Evidence is presented that nitrification under a fallow was more intensive than under a wheat crop.

The field observations are supplemented by laboratory investigations on the accumulation of nitrate under varying moisture and temperature conditions. The favourable temperature range is rather broad, 11°C.–34°C.; there was a sharp optimum moisture content, however, at 17 per cent. with nitrate depletion occurring above 19 per cent., corresponding to 75 per cent. saturation.

35. C. S. Piper. Journ. Agric. Sci. *21*: 762. 1931.
"The Availability of Manganese in the Soil."

Factors governing the availability of manganese in the soil have been investigated, and it has been found that the soil reaction and the oxidation : reduction equilibrium in intimate association have an important bearing on the availability. This has been established by means of laboratory tests and pot experiments on three different soil types, charac-

teristically deficient in available manganese. In these soils the availability of manganese content of the plants, was considerably increased either by making the soil acid or by altering the oxidation : reduction equilibrium in the direction of greater reduction. Laboratory experiments showed that water-logging the soil produced large amounts of water-soluble manganese, and that water-logging in the presence of easily oxidizable organic matter, such as dextrose, produced still greater amounts. Soluble manganese salts when added to soils under aerobic conditions were converted to insoluble compounds. The experiments seemed to indicate that the more highly oxidized compounds of manganese, such as manganese dioxide, were unavailable to plants, and that to be made available they must be reduced to the manganous state.

36. J. A. Prescott. Trans. Sixth Commission, Intern. Soc. Soil Sci., Vol B.: 51. 1933.

"Irrigation and Drainage Problems in Australia."

An account of the problems connected with water-logging and soil salinity in the Murray and Murrumbidgee Irrigation Areas. Troubles are principally due to the excessive use of irrigation water. Remedial measures include the use of lucerne as a dewatering crop and the modification of irrigation methods, following investigations on each soil type.

37. P. M. Rountree. Aust. Jour. Exp. Biol. Med. Sci. *11*: 109. 1933.

"The Bacteriological Oxidation of Sulphur in an Australian Soil."

The oxidation of elementary sulphur in an alkaline South Australian soil, the *Renmark clay loam*, has been studied. The effects on the rate of sulphur oxidation of varying soil moisture content and of varying soil temperature have been determined. The optimum moisture content is found to lie between 60 per cent. and 90 per cent. saturation, and the optimum temperature between 16°C. and 35°C.

A member of the *Thiobacillus* group of soil bacteria has been isolated from sulphur-treated soil, and its growth in sterilized soil studied. By its action the pH value of the soil is changed from 8·4 to 4·5 in 12 days, at which point the large amount of acid accumulated in the soil appears to be the factor limiting further growth. The chief morphological and cultural characters of the organism are described, and its systematic relationships discussed.

(D) Soils: Laboratory Technique.

38. J. A. Prescott and C. S. Piper. C.S.I.R. Pamphlet 8. 1928.

"Methods for the Examination of Soils."

Methods of mechanical and chemical analysis of soils based on critical studies of technique at the Waite Institute, and recommended as a basis for standardization of technique in Australia.

39. C. S. Piper and H. G. Poole. C.S.I.R. Pamphlet 13. 1929.
"The Mechanical Analysis of Soils."

Details are given of the alterations necessary to make the method for the mechanical analysis of soils, as previously developed, conform to the recently adopted method of the International Society of Soil Science. The major changes involved were the separation of four fractions (coarse sand, fine sand, silt and clay), instead of five as previously, and the recording of these fractions on an "oven dry" instead of "ignited" basis. Tables are given showing the times of sedimentation, at different temperatures, for the separation of fine sand, silt, and clay.

A motor dispersion unit and a rubber-lined end runner grinding mill are described.

40. R. J. Best. Jour. Agric. Sci. *21*: 533. 1929.
"A Rapid Electrometric Method for Determining the Chloride Content of Soils."

The Ag-AgCl electrode has been applied to determine the soluble chloride content of soils by direct titration of the soil suspension with $AgNo_3$ solution using a galvanometer to indicate the end point. The method was found to be simple, rapid and accurate.

41. R. J. Best. Jour. Phys. Chem. *34*: 1815. 1930.
"The Application of the Quinhydrone Electrode to the Measurement of the Acid Reaction of Unbuffered Solutions."

In unbuffered solutions of pH value greater than 5 the electrode gives erroneous values.

42. R. J. Best. Jour. Agric. Sci. *21*: 337. 1931.
"A Comparison of Methods for Determining the Hydrogen-ion Concentration of Soils."

The pH values of 55 representative Australian soils have been determined by means of the hydrogen, quinhydrone, and antimony electrodes, and the results compared and discussed.

The limitations of the quinhydrone electrode and the nature of potential drifts have been investigated and their nature elucidated, special attention being paid to alkaline and manganiferous soils.

43. R. J. Best. Jour. C.S.I.R. *4*: 122. 1931.
"Portable Field Apparatus for the Estimation of Chlorides in Soils."

Description of a portable apparatus incorporating the Ag-AgCl electrode, as described in Jour. Agric. Sci. *21*: 533. 1929.

44. C. S. Piper. Second International Congress of Soil Science (U.S.S.R. 1930) *1*: 211. 1932.
"The Preparation of Soil Samples for Mechanical Soil Analysis."

Report of an investigation on seven alternative methods of mechanical soil analysis.

45. C. S. Piper. Jour. Agric. Sci. *22*: 676. 1932.

"The Determination of Sodium by Precipitation as the Triple Salt Sodium-Uranyl-Magnesium Acetate."

The determination of sodium by Barber and Kolthoff's and Kahane's methods has been investigated, with special reference to their suitability for the determination of exchangeable sodium in soils. Bray's modification of Barber and Kolthoff's method, involving 48 hours' standing, was found to give a poor separation from even small amounts of potassium salts, leading to high results for sodium. Kahane's method was more convenient, and gave very satisfactory results, precipitation being complete in 30 minutes. It is a great improvement on the older classical methods which involve the separation and weighing of sodium and potassium chlorides. Moderate quantities of calcium, barium, and ammonium chlorides and potassium up to 0·034 gm. KCl per determination do not interfere. Sulphates only interfere if both Ca and SO_4 are present and the solubility of calcium sulphate is exceeded. Pure solutions of sodium chloride gave recoveries of from 101·5 to 99·3 per cent. Good recovery of sodium chloride added to ammonium chloride extracts of soils was also obtained, the average error being 1·0 per cent.

46. J. S. Hosking. Jour. Agric. Sci. *22*: 92. 1932.

"The Influence of Hydrogen-ion Concentration on the Decomposition of Soil Organic Matter by Hydrogen Peroxide."

Alkaline soils permit a low degree of oxidation, while with acid soils up to 90 per cent. of the organic matter is destroyed. The results obtained with a range of soils suggest that a portion of the organic matter is oxidized irrespective of soil reaction, while the oxidation of the remainder is a definite function of the hydrogen-ion concentration, the relation being expressed by the equation

$$\log \frac{x}{100 - x} = K\ (pH - pH_1)$$

where x is the proportion of oxidizable organic matter destroyed at any given pH value, pH_1 is the reaction value of a soil where the loss is 50 per cent., and K = a constant.

The proportion oxidized further appears to be a definite function of the clay content of soils. Alkaline soils containing free manganese dioxide also show small losses.

The bearing of these findings on the determination of soil organic matter and on the preliminary procedure for mechanical analysis is discussed.

47. J. S. Hosking. Chem. Eng. Min. Rev. *25*: 139. 1933.
"Note on the Determination of Sulphate in Soil Extracts."

The conditions to be observed for the estimation of traces of sulphate in the hydrochloric acid extract of soils are discussed, and a method, given in detail, recommended.

48. J. A. Prescott and H. G. Poole. Journ. Agric. Sci. (in press).
"The Relationship Between Sticky Point, Moisture Equivalent and Mechanical Analysis in Some Australian Soils."

Sticky points and moisture equivalents have been determined on groups of soils from Macquarie Island, the South Australian mallee, Merbein (Victoria), and Renmark (South Australia), as well as on basaltic red loams from Eastern Australia.

Excellent multiple correlations are likely between moisture equivalent and silt, clay and organic matter if the statistical examination is restricted to a closely related group of soils. The contribution to moisture equivalent of organic matter is about 130 per cent. The effect of exchangeable sodium and potassium on moisture equivalent is discussed.

The contribution to the sticky point of the non-colloid fraction is much more variable than has frequently been assumed. As the amount of colloidal material on the soil increases, there is a fall in sticky point associated with the filling of the pore spaces. When the amount of colloidal material reaches 10 per cent. the sticky point rises in proportion to the colloidal content.

II. FIELD CROPS, PASTURES (INCLUDING MINERAL CONTENT OF PASTURES), PLANT NUTRITION, PLANT BREEDING.

(A) Field Crops.

49. J. A. Prescott. Econ. Rec. *4*: 85. 1928.
"The Law of Diminishing Returns in Agricultural Experiment."

A statistical examination of Australian experiments on the manuring of wheat with superphosphate and on the irrigation of lucerne from the point of view of the Law of Diminishing Returns. The Mitcherlich equation is developed to enable the most profitable dressings of superphosphate to be calculated from the results of the field experiments.

50. A. E. V. Richardson and H. C. Trumble. Jour. Agric. Sth. Aust. *32*: 224. 1928.
"The Transpiration Ratio of Farm Crops and Pasture Plants in the Adelaide District."

The transpiration ratio for farm crops was found to vary from season to season with the variations in the intensity of the physical environ-

mental factors during the growing period of the crop, and particularly during the period of maximum transpiration.

The transpiration ratio for cereals and pasture plants varies with the stage of growth at which the crop is harvested. Grasses and clovers produce dry matter at relatively low water cost during winter and spring, but in the final stages of growth transpiration is high in relation to dry matter production.

The application of soluble phosphates resulted in a marked reduction in the transpiration ratio of pasture plants, especially in the early stages of growth.

51. A. E. V. Richardson. Jour. Agric. Sth. Aust. *33*: 297. 1929.
"Increased Efficiency in Wheat Production."

An analysis of the productivity of wheat farms in South Australia, the relationship of rainfall to wheat production, and a discussion of the principles underlying wheat production in a semi-arid environment.

52. A. E. V. Richardson and E. F. Fricke. Jour. Agric. Sth. Aust. *35*: 57. 1931.
"Effect of Nitrogenous Fertilizers on the Growth and Yield of Wheat and Barley."

Results of investigations at the Waite Institute over three years showed that when wheat was sown on well-worked bare fallow the crop did not respond to nitrogenous fertilizers, but a substantial and profitable response was obtained when wheat was sown on stubble-ploughed land. Fallow soil at seeding was found to contain a larger supply of available moisture and of nitrate nitrogen than the stubble soil. These two factors, however, are not of equal importance in a region of liberal winter rainfall, as the lack of nitrates in stubble soil is relatively more serious than the lack of moisture. Marked responses were obtained with nitrogenous fertilizers to barley, and a quantitative relationship was observed between the amount of nitrogen supplied and the yield of barley obtained.

Census studies both on wheat and barley showed that the effect of nitrogen was due mainly to the increased production of ear-bearing tillers per plant.

53. A. E. V. Richardson and H. C. Gurney. Empire Jour. Exptl. Agric. *1*: 193. 1933.
"The Effect of Nitrogenous Fertilizers on the Growth and Yield of Wheat and Barley in South Australia."

The results of investigations at the Waite Institute on the effect of nitrogen on the growth, development and yield of wheat when grown on fallow, on stubble, and in rotation with other field crops.

(B) PASTURES, INCLUDING MINERAL CONTENT OF PASTURES.

54. A. E. V. Richardson. Jour. C.S.I.R. *1*: 92. 1927.
"Mineral Deficiencies in Pastures."
Memorandum prepared for the Imperial Agricultural Research Conference (1927), outlining proposed co-operative investigations on pastures.

55. H. C. Trumble. Jour. Agric. Sth. Aust. *30*: 1210. 1927.
"A Note on *Danthonia*, with Particular Reference to the Effect of Sulphuric Acid on the Germination of the Seed."
Poor and retarded germination in *Danthonia* is frequently due to obstruction of the coleorhiza by the flowering glume, and this may be overcome by treatment with 1·84 sulphuric acid.

56. A. E. V. Richardson. Scottish Jour. Agric. *11*: 249. 1928.
"The Improvement of Grassland."
A discussion of the scientific problems underlying grassland development in Australia.

57. A. E. V. Richardson. Jour. C.S.I.R. *2*: 5. 1929.
"Problems Relating to the Development of Grassland."
A discussion of the ecological, agrostological and genetic problems involved in the improvement of grasslands in Australia.

58. A. E. V. Richardson. C.S.I.R. Pamphlet 17. 1930.
"The Mineral Content of Pastures. Progress Report on Co-operative Investigations at Waite Agricultural Research Institute."

59. H. C. Trumble. Jour. Agric. Sth. Aust. *34*: 38. 1930.
"The Identification of *Phalaris tuberosa* (syn. *bulbosa*) and *Phalaris minor* in Seed Samples and in the Field."
Attention is drawn to confusion between *P. tuberosa* and *P. minor*, and methods of identification, including a seedling root-tip test for *P. minor*, are described.

60. J. Griffiths Davies. C.S.I.R. Bull. 48. 1931.
"The Experimental Error of the Yield from Small Plots of 'Natural' Pasture."
The variability of the yield of small plots of natural pasture was estimated in 1928 by cutting three-eighths of an acre of typical natural pasture in unit plots of 50 square links. The standard error of an unit plot of natural pasture is 32·5 per cent. of the mean yield, a figure that is considerably higher than for field crops generally. The optimum size of the plot was found to be 5 x 90 links in dimension, and ten replications were required to reduce the error to 5 per cent.

61. J. Griffiths Davies and A. H. Sim. C.S.I.R. Pamphlet 18. 1931.
"The Influence of Frequency of Cutting on the Productivity, Botanical and Chemical Composition and the Nutritive Value of 'Natural' Pastures."

A small area of typical unmanured natural pasture was cut at intervals of 2, 4, 7, 10 and 20 weeks, for the two growing periods of 1927 and 1928. It was concluded that severe defoliation reduced the total yield of produce materially, and greatly modified the botanical composition, but that with decreasing frequency of cutting higher total yields of dry matter were obtained. The optimum return of nutrients per acre was obtained when the pasture was cut at intervals of seven weeks.

62. A. E. V. Richardson, H. C. Trumble and R. E. Shapter. C.S.I.R. Bull. 49. 1931.
"Factors Affecting the Mineral Content of Pastures."

Pure species grown under similar soil conditions and harvested at a definite growth stage showed wide differences in mineral and nitrogen content, mineral accumulation in relation to transpiration, and absorption of phosphorus from insoluble phosphate. Growth stage was found to exercise a determining influence on the nitrogen and mineral content of pasture species. Nitrogen assimilation and absorption of essential nutrients are most active at the tillering stage; photosynthesis rises to a maximum shortly after the flowering stage, whilst transpiration losses are greatest during the final stages of growth.

The composition of the plant was found to be affected by the differences in the fertility of the soil. The application of soluble phosphate to phosphate-deficient soils increases the phosphorus content of the herbage. The supply of minerals in a pasture can be increased by the establishment of suitable species, the utilization of the herbage by appropriate methods of pasture management, and the maintenance of soil fertility with suitable fertilizers.

63. H. C. Trumble and J. Griffiths Davies. Jour. C.S.I.R. *4*: 140. 1931.
"The Rôle of Pasture Species in Regions of Water Rainfall and Summer Drought."

A discussion of the herbage species suitable for the "Mediterranean" climatic regions in Southern Australia. Three distinct habitats are recognized, based mainly on their water relationships. The improvement of pastures within each belt is primarily determined by the species occurring in the pastures, and the improvement of soil fertility and methods of pasture management cannot find full expression without the replacement of the annual non-legumes by perennial herbage plants.

It was concluded that the most promising herbage species were

Phalaris tuberosa, Lolium perenne, Wimmera rye-grass, *Danthonia* spp., *Ehrharta calycina, Trifolium subterraneum, Medicago sativa, Atriplex semibaccatum;* with, in addition, *Dactylis glomerata, Trifolium repens* and *T. pratense* for irrigated pastures.

64. A. E. V. Richardson. Jour. C.S.I.R. *5*: 141. 1932.
"The Mineral Content of Pastures. Report on Co-operative Investigations in Progress at the Waite Agricultural Research Institute."

65. A. E. V. Richardson, H. C. Trumble and R. E. Shapter. C.S.I.R. Bull. 66. 1932.
"The Influence of Growth Stage and Frequency of Cutting on the Yield and Composition of a Perennial Grass—*Phalaris tuberosa.*"

Growth stage was found to exercise a determining influence on the protein, crude fibre, carbohydrate and mineral content.

A downward migration occurred of portions of the nitrogen and phosphate of the herbage to the basal portion of the stem and to the root system.

A substantial and absolute loss occurred from all portions of the plant, including the herbage, basal internodes, and root system during the final stage of growth. The migration of potash from the plant to the soil amounted to 27·8 per cent. of the total intake.

The effect of various systems of defoliation on the yield, protein and phosphorus content of the plant was investigated.

66. A. B. Cashmore. C.S.I.R. Bull. 69. 1932.
"An Investigation of the Taxonomic and Agricultural Characters of the *Danthonia* Group."

The "lumping" of *Danthonia* species is undesirable, owing to the individuality of the species groups. Considerable strain variation exists, and types of superior agronomic value have been isolated. The extended production period of *Danthonia* is well suited for wool production.

67. A. E. V. Richardson. C.S.I.R. Bull. 71. 1932.
"Investigations on Irrigated Pastures: (1) The Yield and Botanical Composition of an Irrigated Permanent Pasture under Various Systems of Pasture Management."

A seeded pasture, established under irrigated conditions on a typical reclaimed swamp area, proved to be highly productive under rotational grazing by sheep. Monthly cuts gave a total yield of 8·7 tons of dry matter per acre during the season following establishment, and averaged over 25 per cent. protein and 1 per cent. phosphoric acid.

The yield of herbage was 30 per cent. greater under rotational grazing at 28-day intervals than under cutting at similar intervals. This

difference was attributed mainly to the substantial return of nutrients, in the form of animal excrement, under grazing conditions. Under rotational grazing a good balance of rye-grass and clover was maintained. Under mowing, however, the pasture rapidly became clover dominant.

Mowing at 56-day intervals gave a 31 per cent. higher total yield and a more suitable feed for fattening sheep than mowing at 28-day intervals.

The mean carrying capacity of 70 acres of permanent pasture over a period of twelve months was 16·2 sheep per acre.

68. H. P. C. Gallus. C.S.I.R. Bull. 71. 1932.
"Investigations on Irrigated Pastures. (2) The Chemical Composition of Irrigated Pastures at Wood's Point, South Australia."

The nitrogen and phosphoric acid content of irrigated pasture is high throughout the year.

Changes in yield and botanical composition caused by mowing instead of grazing are accompanied by changes in chemical composition.

Mowing at 56-day intervals instead of 28-day intervals lowers the percentage of nitrogen and phosphoric acid. Pasture cut at 56-day intervals showed the lowest protein, ether extract, and ash, and highest fibre and nitrogen-free extract.

69. H. C. Trumble. Jour. C.S.I.R. *5*: 152. 1932.
"Preliminary Investigations on the Cultivation of Indigenous Saltbushes (*Atriplex* spp.) in an Area of Winter Rainfall and Summer Drought."

Saltbush species may be readily established from seed under field conditions, provided seeding is effected with due regard to the temperature and moisture conditions of the surface soil.

Atriplex semibaccatum is of especial value for its summer production, low water requirement, deeply penetrating root system, and high content of protein, phosphorus and sodium chloride.

Limitations to the use of saltbushes include susceptibility to competition, doubtful longevity, and high nitrogen requirement.

70. H. C. Trumble. Imp. Bur. Plant Gen.: Herbage Plants, Bull. *7*: 17. 1932.
"The Improvement of *Phalaris* Species by Selective Breeding."

Little ecotypical selection appears to have occurred in *Phalaris tuberosa*, and the unit for strain-building has been the single plant. Plants are selected on the basis of their own characteristics, and on the performance of their selfed and out-crossed progeny. Selection has aimed at increased leafiness, density and vigour, with a high degree of adaptability to sward conditions.

71. H. C. Trumble and K. M. Fraser. Jour. Agric. Sth. Aust. *35*: 1341. 1932.
"The Effect of Top-dressing with Artificial Fertilizers on the Annual Yield, Botanical Composition, and Carrying Capacity of a Natural Pasture over a Period of Seven Years."

Dressings of superphosphate, basic slag, and rock phosphate each increased the production from a natural pasture over a period of seven years. The greatest increase resulted from a dressing of 185 lb. superphosphate and 78 lb. nitrate of soda per acre.

An annual application of 185 lb. superphosphate resulted in the maintenance of 60 per cent. more sheep per acre.

Top-dressing with soluble phosphates changed the dominantly perennial *Danthonia* pasture to an unstable association of annual species of doubtful value.

72. H. C. Trumble. Jour. Agric. Sth. Aust. (in press).
"The Agricultural Features of *Phalaris tuberosa* and Allied Forms."

The principal features of *Phalaris tuberosa* are its capacity for production during autumn and winter, its drought-resistance, stability, adaptability to widely varying soil types, and varying conditions of management, and its capacity to grow in association with subterranean clover. This grass is highly sensitive to competition, particularly from the rye-grasses, during the year of establishment.

The structure and depth of penetration of the root system are important in relation to both drought-resistance and susceptibility to competition during the first year.

The drought-resistance of *Phalaris tuberosa* is not associated with a low transpiration rate, but appears to be governed by its deep-rooting habit and a capacity to enter a condition of anabiosis prior to the onset of dry conditions. Associated with these features is the close coincidence of the plant's life-cycle with the periodicity of the Mediterranean type of climate.

73. A. E. V. Richardson. Herbage Reviews *1*: 96. 1933.
"The Effect of Climate on the Composition of Pasture Plants."

The protein and mineral content of pastures from tropical and subtropical areas are in general lower than those recorded for pastures in cold temperate regions.

Apart from the known influence of species, growth stage, soil type, and fertilizers on the composition of pastures, it is possible that the explanation may be found in terms of differences in the effect of the two contrasting types of climate on the uptake of nitrogen, phosphorus and minerals on the one hand, and the assimilation of carbon on the other, the carbon-nitrogen ratio tending to be high in tropical climates and low in temperate climates.

(c) Plant Nutrition.

74. A. H. K. Petrie. Jour. C.S.I.R. *5* : 177. 1932.
"A Note on the Relation of Mineral Nutrition to Transpiration in Plants."
The effect of nitrate treatment in reducing the transpiration ratio of *Atriplex semibaccatum* cannot be explained in terms of reduction of the osmotic pressure of the cell-sap. Other possible interpretations are discussed.

75. L. A. T. Ballard. Aust. Jour. Exp. Biol. *11* : 161. 1933.
"The Effect of Nitrate Supply on Transpiration Ratio in Plants."
The effect of nitrate in reducing transpiration ratio, which is the ratio of water transpired to dry matter produced up to any point, is due, not to an effect on the transpiration rate per unit weight of leaf, but to an effect on growth. This effect is analysed into its various components.

76. A. H. K. Petrie. Aust. Jour. Exp. Biol. Med. Sci. *11* : 25. 1933.
"The Intake of Ions by the Plant and its Relation to the Respiration of the Root."
An hypothesis is developed wherein four mechanisms are suggested as causing intake of ions by the plant from its environment. It is shown that in terms of this hypothesis the rate of intake may be dependent on the rate of respiration of the absorbing region of the root. Some data are then presented which agree with the view that such a relationship holds.

(d) Plant Breeding.

77. H. C. Gurney. Aust. Jour. Exp. Biol. Med. Sci. *7* : 215. 1930.
"The Inheritance and Linkage Relations of Xantha Seedlings in Maize."
The presence of two duplicate genes, xn_1 and xn_2, determining the xantha seedling character was confirmed. A definite linkage between the endosperm colour factor R and one of the factors xn_1, for xantha seedling was found, an average of results giving a cross-over value of 23·4 per cent.

78. H. C. Gurney. Aust. Jour. Exp. Biol. Med. Sci. *8* : 241. 1931.
"The Cytology of Rye."
A description of the cytology of rye from early meiotic prophase to mitotic telophase is given. It was possible to identify each individual bivalent at early anaphase by its size, shape, and spindle-fibre attachment.

79. H. C. Gurney. Jour. Agric. Sth. Aust. *35* : 1178. 1932.
"A Classification of South Australian Wheat Varieties."

80. I. F. Phipps and H. C. Gurney. Aust. Jour. Exp. Biol. Med. Sci. *10*: 215. 1932.

"A Preliminary Note on the Origin of a B-type Speltoid in *Triticum vulgare*."

A speltoid occurring in the cross between Egyptian 8 (♀), an awned variety, and Hard Federation (♂), an awnless variety, was studied both genetically and cytologically.

The evidence presented indicates that the speltoid is of the B-type, with 41 somatic chromosomes, and that the lost chromosome is the one bearing the gene for awnedness contributed by the Egyptian 8 parent.

81. H. C. Gurney. Aust. Jour. Exp. Biol. Med. Sci. *11*: 123. 1933.

"The Cytology of Wheat x Rye Hybrids of the Fifth and Sixth Generation."

The hybrids could be divided into (a) intermediate very variable type, (b) more stable wheat-like type, (c) rye-like and also very spelt type, and (d) dwarfs. Chromosome counts ranged from 15 to 21 in the tall plants, and from 13 to 18 in the dwarfs at meiotic metaphase. In the dwarfs there were also fewer univalents which did not line up on the plate at metaphase, and fewer laggards. It is suggested that dwarfing may be caused by chromosome deficiency, as well as by Mendelian factors, the dwarfing in the former case occurring in no constant ratio. In the prophases, in addition to a number of bivalent loops, univalents were seen which were merely constricted off from spireme ends, and tended to remain outside the second contraction knot. The metaphase plate stage and subsequent anaphase were very irregular, non-orientation, trivalent and tetravalent formation, and lagging of univalents being common. Univalents were frequently lost by non-inclusion in the daughter nuclei. The rye-like type showed a predominance of typical rye bivalents, and the wheat-like types showed a predominance of the recognizable wheat bivalents, and also had chromosome numbers ranging from 20 to 22.

82. H. C. Gurney. Aust. Jour. Exp. Biol. Med. Sci. *11*: 157. 1933.

"A Note on the Use of Feulgen's Reaction as a Critical Stain for Wheat Cytology."

A brief description of the application of this reaction to chromosome staining in wheat pollen mother cells and root-tips is given, and the convenience of the method and superiority of the results, particularly for prophase figures, is pointed out.

83. H. C. Trumble and I. F. Phipps. Jour. C.S.I.R. *6*: 170. 1933.
"The Inheritance of Fluorescence in Hybrids between Perennial Rye-grass and Wimmera Rye-grass."

The evidence presented indicates that: (1) fluorescence is inherited as a dominant character dependent upon one and possibly two genetic factors giving 3 : 1 and 9 : 7 ratios respectively; (2) there is no intimate relation between fluorescence of seedling and annual habit.

It is argued that since Wimmera rye-grass is doubtless of recent hybrid origin, and is a mixture of many and diverse types, there is no justification for the botanical equivalents which have been applied.

The evidence available suggests that Wimmera rye-grass has arisen by hybridization between *L. multiflorum* and *L. rigidum*.

III. FUNGUS AND VIRUS DISEASES OF PLANTS.

84. G. Samuel. Jour. Agric. Sth. Aust. *28*: 1071. 1926.
"Black Rot of Cabbages and Cauliflowers in South Australia."

85. G. Samuel. Jour. Agric. Sth. Aust. *29*: 328. 1926.
"Tomato Diseases."

86. G. Samuel. Jour. Agric. Sth. Aust. *29*: 1036. 1926.
"Some of our Needs in Combating Loss from Plant Diseases."

87. G. Samuel. Trans. Roy. Soc. Sth. Aust. *50*: 245. 1926.
"Note on the Distribution of Mycorrhiza."

The exceptional abundance of endotrophic mycorrhiza in the roots of oat plants from the volcanic soil round Mount Gambier was recorded. Also the presence of endotrophic mycorrhiza in the roots of legumes, cereals, and plants belonging to a number of other families from different localities in South Australia. Ectotrophic mycorrhiza was recorded for *Eucalyptus rubida*.

88. H. A. Pittmann. Jour. C.S.I.R. *1*: 74. 1927.
"Spotted Wilt of Tomatoes."

An account of the experiments which first proved that the virus disease, "spotted wilt" of tomatoes, is transferred from plant to plant by species of thrips. Some of the thrips used were identified as *Thrips tabaci*.

89. G. Samuel. Ann. Bot. *41*: 375. 1927.
"On the Shot Hole Disease caused by *Clasterosporium carpophilum*, and on the Shot Hole Effect."

The details of infection of almond leaves by the fungus *Clasterosporium carpophilum* are described. The germ-tubes of the spores are surrounded by a mucilaginous sheath, which fixes them to the substratum; they are negatively phototropic, and they enter the leaf by direct penetra-

tion of the cuticle. The shot-hole effect is due to a reaction of the host plant to the injury caused by the fungus, and the details of the formation of the abscess layer are described.

90. G. Samuel. Jour. C.S.I.R. *1*: 273. 1928.

"A Plant Pathology Glasshouse at Adelaide."

A plan and some details of construction of the insect-proof glasshouse erected with funds supplied by the Council for Scientific and Industrial Research for the investigation of the spotted wilt disease of tomatoes.

91. G. Samuel. Jour. Agric. Sth. Aust. *32*: 40. 1928.

"Two Stunting Diseases of Wheat and Oats."

A preliminary note on the seedling diseases of cereals which were later shown to be due to the eel-worm, *Heterodera schachtii*, and to the fungus *Rhizoctonia solani*.

92. G. Samuel. Jour. Agric. Sth. Aust. *34*: 154. 1930.

"Tomato Diseases in South Australia and How to Control Them."

An illustrated bulletin describing general methods for the avoidance of disease in glasshouse tomatoes, and the symptoms, cause and control of some twenty tomato diseases met with in South Australia.

93. G. Samuel, J. G. Bald, and H. A. Pittman. C.S.I.R. Bull. 44. 1930.

"Investigations on Spotted Wilt of Tomatoes."

A full description is given of the symptoms and occurrence of the "spotted wilt" disease of tomatoes in Australia. An account is also given of the experiments which proved that the thrips, *Frankliniella insularis*, is the main insect vector of the disease in South Australia. Infective thrips were found to remain infective for at least twenty-four days, but they did not transmit the infection to every plant on which they fed. Tobacco and some other solanaceous plants were found to be host plants of the disease. None of 48 commercial varieties of tomato was found to possess any appreciable resistance. The small red currant tomato was found to be fairly resistant, and crosses were made between it and commercial varieties. Experiments on control of the disease by insecticidal sprays and dusts did not give encouraging results.

94. G. Samuel. Jour. Agric. Sth. Aust. *34*: 746. 1931.

"Summary of Plant Disease Records in South Australia for the Two Years ending 30th June, 1930."

95. G. Samuel. Anns. Appl. Biol. *18*: 494. 1931.
"Some Experiments on Inoculating Methods with Plant Viruses, and on Local Lesions."

It is shown by means of dilution tests that a light rubbing with virus, in which no visible wound is produced on the leaf, is a more effective method of mechanical inoculation than scratching with a needle in the case of five viruses which affect tobacco. A method of inoculating these viruses with a ground-glass spatula is suggested. Observations are given on the character of the primary lesions of the different viruses, and on the influence of temperature upon them. An intimate relation between the vascular system and the path of travel of the virus was revealed by the application of the iodine test to leaves inoculated a few days previously with yellow tobacco mosaic.

96. J. G. Bald and G. Samuel. C.S.I.R. Bull. 54. 1931.
"Investigations on 'Spotted Wilt' of Tomatoes, II."

It was found that adult thrips of the species *Frankliniella insularis* were unable to transmit the virus of spotted wilt after feeding on a diseased plant. It was essential that they should have fed on a diseased plant during their larval life in order to become vectors of the disease. The incubation period of the virus in the larva was found to be between five and seven days.

It was found possible to transmit spotted wilt by mechanical inoculation with great certainty if the leaves of plants were merely rubbed, without producing injury, with virus obtained from a fairly recently diseased plant. This method allowed certain virus properties to be determined. The virus is very short-lived, losing most of its activity within three hours at room temperature. It is also very sensitive to heat, being killed by heating for ten minutes at a temperature in the neighbourhood of 42°C.

The disease has a wide host range. Thirty species in ten genera of the Solanaceae were infected, and Iceland poppies, nasturtiums, and zinnias were found naturally infected with spotted wilt in suburban gardens.

97. G. Samuel and J. G. Bald. Nature *128*: 494. 1931.
"*Thrips tabaci* as a Vector of Plant Virus Disease."

Experimental work verified the fact that *Thrips tabaci* was a vector of tomato spotted wilt, as well as *Frankliniella insularis*.

98. G. Samuel. Phytopath. *22*: 613. 1932.
"*Macrosporium solani* on Tomato Fruits."

Infection of fruit is rare, but when it takes place the symptoms are hard, sunken lesions at the stem or calyx end, and not "nailhead spots".

99. G. Samuel and S. D. Garrett. Phytopath. *22*: 827. 1932.
"*Rhizoctonia solani* on Cereals in South Australia."

The fungus *Rhizoctonia solani* kills back the roots of wheat, oats and barley seedlings in mallee soils, so that the plants become stunted. The disease usually occurs in small, definite patches a few feet across. Pasture plants may also be affected. The disease is most active at low soil temperatures, and if plants are not killed in the early stages they may recover with the advent of warmer weather.

100. G. Samuel. Jour. Agric. Sth. Aust. *36*: 300. 1932.
"Summary of Plant Disease Records in South Australia for the Two Years ending June 30, 1932."

101. S. D. Garrett. Jour. Agric. Sth. Aust. (in press).
"Factors Affecting the Severity of 'Take-all'."

The growth of the take-all fungus, *Ophiobolus graminis*, was studied in sterilized and non-sterilized soil and sand. Growth was vigorous in the sterilized soil and sand, somewhat less so in the non-sterilized sand, and was almost completely inhibited in the non-sterilized soil. The results were attributed to the antagonistic effects of the soil bacteria. Counts of bacterial numbers in mallee sandhill and clay flat soils showed that they were in inverse proportion to the rate of growth of take-all along wheat roots in these soils. The lessened susceptibility of mallee soils to take-all after some 20-25 years of cultivation was attributed to the gradual increase in fertility, with the accompanying increase of soil bacteria antagonistic to the disease.

By means of soil-temperature tank experiments, using a poor silica sand with nutrients, it was shown that the true temperature-disease curve for take-all rose continuously to 24°C., with a slight fall thereafter, confirming the work of Henry. Previous curves showing maximum disease at low temperatures did not take account of the antagonistic effect of the soil bacteria, which becomes marked above 18°C. *Ophiobolus* inoculum was rapidly destroyed in moist soil at a temperature of 25°C.

An analysis of past records of take-all showed a marked correlation between abundant spring rainfall and the prevalence of the disease. This was discussed from the point of view of the theory of wind dispersal of take-all by means of ascospores.

102. G. Samuel. Anns. Appl. Biol. (in press).
"The Movement of Tobacco Mosaic Virus within the Plant."

The movement of mosaic virus in tomato plants was investigated, and it was found: (1) that there was no movement from the inoculated leaf for the first three or four days; (2) that when the virus passed out of the inoculated leaf it travelled first to the roots of the plants with such speed

that it could seldom be intercepted at intervening positions in 12-hourly tests; (3) usually about a day later it travelled with equal rapidity to the top of the plant; (4) in the earliest stages of entering the stem virus particles were often separated by considerable distances; (5) the virus entered developing fruit almost as soon as it entered the stem, but mature leaves were not invaded for days or weeks; (6) complete invasion never occurred when large field plants of tobacco or tomato were inoculated.

103. G. Samuel and J. G. Bald. Anns. Appl. Biol. *20*: 70. 1933.
"On the Use of the Primary Lesions in Quantitative Work with Two Plant Viruses."

The rubbing method of inoculation of viruses proposed by Holmes, which allows the development of the primary lesions, can be used for fairly accurate quantitative work in comparison of virus strengths if certain precautions are adopted. A standard method of inoculation with a glass spatula, and comparison of viruses on opposite halves of the same leaves were found to be the most important points to observe, and the use of the method was illustrated by plotting the curve of "ageing" of tomato spotted wilt virus. The curve was found to be of the logarithmic type.

104. G. Samuel and J. G. Bald. Jour. Agric. Sth. Aust. *37*: 190. 1933.
"Tomato Spotted Wilt on Tobacco."

A brief description, with illustrations, of the tobacco disease caused by the virus of tomato spotted wilt.

105. J. G. Bald and G. Samuel. Anns. Appl. Biol. (in press).
"A Preliminary Investigation of Some Factors Affecting the Inactivation Rate of the Virus of Tomato Spotted Wilt."

The rapid loss of virulence of the virus of tomato spotted wilt in sap expressed from diseased plants was found to be hastened by stirring, by the bubbling of air through the inoculum, and by the addition of certain chemical reagents, including oxidizing reagents. Loss of virulence was delayed by two reducing agents, sodium sulphite and sodium nitrite. The former had the greatest effect, the virus remaining active for more than 36 hours in a 0·2 per cent. solution at a temperature of 22°C. Other reducing agents hastened inactivation, but the oxidation-reduction potentials of the virus-containing systems were not known.

106. G. Samuel, J. G. Bald, and C. M. Eardley. Phytopath. *23*: 641. 1933.
" 'Big Bud', a Virus Disease of the Tomato."

A description of a tomato disease, in which the main symptoms are abnormalities in the floral parts, including enlarged, adherent calyces and transformation of petals and ovaries into green leaf-like structures. The stems of affected plants become thicker than those of normal plants, owing to the formation of an abnormal tissue in association with the internal

phloem. The disease is a virus disease, transmissible by budding and grafting, but not by mechanical inoculation. No insect vectors of the disease have yet been discovered.

107. G. Samuel and S. D. Garrett. Phytopath *23*: 721. 1933.
"Ascospore Discharge in *Ophiobolus graminis* and its Probable Relation to the Development of 'Whiteheads' in Wheat."

The greatest loss from take-all in South Australia occurs in the whitehead stage, and in seasons when showery weather lasts almost until the crop is in ear. During the bad take-all season of 1932 crops showing severe whitehead infection were found to have early diseased patches, in which the plants had died before flowering, and on which the spore cases of the take-all fungus were present. It was discovered that the spore cases ejected ascospores into the air when moistened, at the rate of several hundred per minute from a single diseased wheat culm. The spores could be carried in the wind, and they remained alive for as long as a week under cool moist conditions. It was therefore suggested that epidemics of whiteheads may result from wind-disseminated ascospores.

IV. INVESTIGATIONS ON ECONOMIC INSECTS.

(A) Pasture and Cereal Crops.

108. J. Davidson. Jour. Agric. Sth. Aust. *34*: 378. 1930.
"Eelworms (*Heterodera schachtii* Schm.) Affecting Cereals in South Australia."

The eelworm (*Heterodera schachtii* Schm.) was found infesting roots of cereals over a wide area of South Australia. Preliminary observations have been made on its distribution, together with recommendations on control measures.

It is evident that eelworm attack affects the yield to some extent. The loss is greater in some seasons than in others, and appears to be associated with various factors affecting the growth of the crop.

109. J. Davidson. Jour. Agric. Sth. Aust. *34*: 224. 1931.
"White Grubs."

This is a general account of the habits of the larvae of scarab beetles and the damage caused to pastures and to the roots of cereals.

110. J. Davidson. Aust. Jour. Exp. Biol. Med. Sci. *8*: 143. 1931.
"The Influence of Temperature on the Incubation Period of the Eggs of *Sminthurus viridis* L. (Collembola)."

The results of tests with 77 egg batches show that the incubation period of the eggs of *S. viridis*, when moisture is favourable, fit an hyperbola $d(t - c) = K$, where d = period of development, t = temperature, c = developmental zero = 5·5°C., K = 161°C.

111. J. Davidson. Aust. Jour. Exp. Biol. Med. Sci. *10*: 1. 1932.
"Factors Affecting Oviposition of *Sminthurus viridis* L. (Collembola)."

S. viridis, popularly known as the "lucerne flea", lays its eggs in batches on the soil; the eggs are coated with soil-excreta.

Soil moisture plays an important part in relation to the oviposition response. With Waite Institute soil the number of eggs laid decreased rapidly below 12 per cent. moisture. Saturated soil is unfavourable.

Soil reaction influences oviposition. The best results were obtained about pH 6·4, but the insect oviposits freely between pH 5·5 and 7·5. The physical character of the soil, especially its water-holding capacity, is important, and is closely associated with the influence of soil reaction.

112. J. Davidson. Aust. Jour. Exp. Biol. Med. Sci. *10*: 65. 1932.
"On the Viability of the Eggs of *Sminthurus viridis* L. (Collembola) in Relation to their Environment."

S. viridis has a definite seasonal occurrence in South Australia. It is absent during the dry season. Certain of the eggs are resistant to dryness, and carry the species over this period. The number of eggs which survive the dry conditions depends upon (a) the stage of development attained by the embryo when the dry season sets in, (b) the severity and duration of the dry season. Eggs which have completed nearly half their development are most resistant.

113. J. Davidson. Aust. Jour. Exp. Biol. Med. Sci. *11*: 9. 1933.
"The Environmental Factors Affecting the Development of the Eggs of *Sminthurus viridis* L. (Collembola)."

Temperature and moisture conditions at the soil surface are the important factors affecting development and hatching of the eggs of *S. viridis.* When moisture conditions depart from the optimum, either in the direction of "too wet" or "too dry", development is retarded and hatching becomes irregular. When the soil is drying out, development may be inhibited, but the eggs can withstand considerable periods of dryness. Unmated females lay apparently normal egg batches, but from ten unmated females none of the eggs hatched.

114. J. Davidson. Jour. Agric. Sth. Aust. *36*: 994. 1933.
"On the Control of the 'Lucerne Flea' (*Sminthurus viridis* L.) in Lucerne in South Australia."

An account is given of field experiments dealing with fluctuations in the numbers of *S. viridis* in lucerne pasture in South Australia during the year. These are dependent on meteorological conditions. The information obtained gives a useful guide to the correct timing of control measures.

Lime sulphur, strength 1 gallon in 50-60 gallons of water, sprayed at the rate of 80 gallons per acre, gave complete control. It is necessary to safeguard reinfestation of the treated area with the insects from the sur-

rounding areas. The pasture should be close grazed or cut before treatment.

Summer irrigation over a period of three weeks in summer resulted in hatching out the over-summering eggs and freeing infested plots of lucerne; the insects which hatched out were unable to survive the high summer temperatures and subsequent dryness.

115. J. Davidson. Aust. Jour. Exp. Biol. Med. Sci. *11*: 59. 1933.
"The Distribution of *Sminthurus viridis* L. (Collembola) in South Australia, Based on Rainfall, Evaporation, and Temperature."

The possible geographical distribution of *S. viridis* in Australia is determined by the ratio of rainfall to evaporation.

Saturation deficiency of the air is the major factor influencing evaporation. For this State the mean monthly values for saturation deficit have been expressed in terms of evaporation. When the mean monthly ratio is less than 1, dryness may inhibit the occurrence of the insects.

The months and approximate areas in South Australia in which rainfall exceeds evaporation have been defined. From these areas the possible range of distribution of *S. viridis* has been determined.

116. J. Davidson. S.A. Dept. Agric. Bull. 286. 1933.
"The 'Lucerne Flea' Problem in South Australia."

A general survey of the "Lucerne flea" problem, based on experimental studies of the biology of *S. viridis* and field experimental work.

Recommendations for dealing with the problem are discussed. These include: (a) for restricted infested areas, palliative measures by spraying, fallowing, etc.; (b) for general pasture areas, improvement in mixed pastures of clover and grasses, and a thorough investigation of the aspect of possible biological control of the insect by predators.

117. J. Davidson. C.S.I.R. Bull. (in press).
"The 'Lucerne Flea' (*Sminthurus viridis* L.) in Australia."

This is a detailed account of experimental work on the biology of *S. viridis* and its control. A survey is given of the areas in Australia in which the species could become established, and those areas in which it could increase to become of serious economic importance. Recommendations for dealing with the problem are discussed.

(B) Orchard and Market Garden Crops.

118. J. Davidson and J. G. Bald. Bull. Ent. Res. *21*: 365. 1930.
"Description and Bionomics of *Frankliniella insularis* Franklin (Thysanoptera)."

Frankliniella insularis occurs on various food-plants in South Australia, and is a vector of the virus of spotted wilt disease of tomatoes. It is common during the warmer months of the year (November to April).

An account is given of the egg, larval and pupal stages, and their rate of development in relation to temperature.

The complete life-cycle under glasshouse conditions occupied 36-39 days when the mean temperature was 66°F. The period varied from 13 to 41 days with mean temperatures varying from 89·5°F. to 64·1°F.

119. J. Davidson. Jour. Agric. Sth. Aust. *35*: 1381. 1932.

"Some Observations on the Causes of Surface Blemishes of Oranges in South Australia."

Observations were made during the season 1931-1932 on the causes of the rind blemishes of oranges in South Australia. The blemishes can be divided into three categories:

(1) Blemishes due to mechanical injury, particularly by wind blowing the fruit against twigs, etc.

(2) Blemishes due to damage caused by insects feeding on the rind, particularly on the very young fruit.

(3) Blemishes due to Oleocellosis, damage caused by the destruction of the oil cells in the rind; the oil is toxic to neighbouring cells at certain periods of the growth of the fruit.

Certain recommendations are made, based on the year's observations.

120. J. Davidson. The Fruit World of Australasia *34*: 555. 1933.

"Report on Thrips Investigation."

The species of thrips, *Thrips imaginis* Bagnall, occurs in plague numbers in certain years in the southern States of Australia, and causes considerable damage to apple blossom, resulting in reduction in setting of fruit.

A detailed investigation of the problem has been commenced as a co-operative enterprise between the Council for Scientific and Industrial Research, the Waite Institute, the Thrips Investigation League, and the Departments of Agriculture of certain States.

The investigation is being directed by the Head of the Department of Entomology of the Waite Institute. The present report deals with the progress of the investigation during 1932 to 1933.

121. J. W. Evans. Jour. C.S.I.R. *6*: 99. 1933.

"Some Preliminary Tests on the Control of *Thrips imaginis* Bagnall."

An account of experiments made with certain materials for the purpose of testing their value as thrips repellents. Pyrethrum powder, even when mixed with sulphur in the proportion of 1 part of pyrethrum to 10 parts of sulphur, was shown to retain its strength as a repellent for two days.

122. J. W. Evans. Jour. C.S.I.R. *6*: 145. 1933.

"The Seasonal Fluctuations in Numbers of *Thrips imaginis* Bagnall and Associated Blossom Thrips."

Thrips infestations have been shown to be primarily dependent on the weather conditions ruling during the four months from May-August. This paper is an account of a study in progress, of the seasonal fluctuations in numbers of *T. imaginis*, being made with the purpose of correlating these fluctuations with meteorological conditions.

123. J. Davidson. Jour. Agric. Sth. Aust. *32*: 798. 1929.

"Report on the Occurrence of the Woolly Pear Aphis (*Eriosoma lanuginosum* Hartig, *E. pyricola* Baker and Davidson), with Recommendations as to its Control."

(c) Miscellaneous.

124. J. Davidson and H. Henson. Ann. Appl. Biol. *16*: 458. 1929.

"The Internal Condition of the Host Plant in Relation to Insect Attack, with Special Reference to the Influence of Pyridine."

The resistance or immunity of a plant to insect attack may be due to particular features of its morphology or anatomy. In most instances, however, it appears to be due to the presence or absence of particular substances on the tissues of the plant, which render it unsuited to the insect.

The results of a number of experiments dealing with the influence of various substances when absorbed into *Vicia faba,* on aphides (*A. rumicis*) infesting the plants are described. Experiments were carried out, particularly with pyridine, which was added to the soil on which the plants were growing. A marked reduction in the numbers of the insects was obtained by low concentrations of this substance.

125. J. Davidson. Jour. Agric. Sth. Aust. *34*: 741. 1931.

"Insects Observed on Crops in South Australia during the Period June, 1928, to June, 1930."

Observations on the various species are given, with special reference to their economic significance during the period under review. This is the first paper. It will be followed by similar observations biennially.

126. J. Davidson and J. G. Bald. Aust. Jour. Exp. Biol. Med. Sci. *8*: 139. 1931.

"Sex Determination in *Frankliniella insularis* Franklin (Thysanoptera)."

Unmated females of *F. insularis* develop into males only. The eggs from mated females give rise to both sexes. The explanation of this appears to be that some of the eggs are unfertilized, which give rise to males; the fertilized eggs give rise to females.

127. J. Davidson. Jour. Agric. Sth. Aust. *36*: 283. 1932.

"Insects Observed on Crops in South Australia during the Period June, 1930, to June, 1932."

This is the second list of records.

128. J. Davidson. Nature *129*: 867. 1932.

"Resistance of Eggs of Collembola to Drought Conditions."

The activity and abundance of Collembola are closely associated with the moisture of their environment. The species survive dry periods in the egg stage. This is well illustrated in the case of *S. viridis*. An experiment is described in which 100 egg batches (estim. 4,500 eggs) are dried after varying periods of development. A high proportion of the eggs which had attained about 50 per cent. development, when the extreme dryness inhibited further development, survived the drought period.

129. J. Davidson. Jour. Agric. Sth. Aust. *36*: 1148. 1933.

"The Species of Blowflies in the Adelaide District of South Australia and their Seasonal Occurrence."

Records of the number and species of blowflies caught in traps throughout a complete year, September, 1931 to 1932, at the Waite Institute, have been analysed. The important species recorded were the European green blowfly, *Lucilia sericata* Meigen; the large brown blowfly, *Calliphora stygia* Fab.; the lesser brown blowfly, *Calliphora nociva* Hardy; the secondary green blowfly, or hairy maggot fly, *Chrysomyia rufifacies* Macq.; the small metallic green blowfly, *Microcalliphora varipes* Macq. The first three species are primary flies associated with the blowing of sheep; the remaining species are secondary flies. The various species have a definite seasonal incidence.

130. J. Davidson. Nature *131*: 837. 1933.

"Effect of Rainfall-Evaporation Ratio on Insects Inhabiting the Soil Surface."

Certain insects inhabiting the soil surface are markedly affected by soil moisture, largely owing to its influence on the humidity of their surroundings. Soil moisture is primarily dependent on the ratio of rainfall to evaporation; important secondary factors are soil type and its vegetative covering.

A method has been used for South Australia whereby saturation deficiency is expressed in terms of evaporation from Adelaide records. By this means the values of the mean monthly rainfall-evaporation ratio have been obtained. This is useful in ecology as an index to the moisture conditions at the soil surface throughout the year.

131. J. Davidson and D. C. Swan. Bull. Ent. Res. *24*: 351. 1933.
"A Method for Obtaining Samples of the Population of Collembola (Symphypleona) in Pastures."

132. J. W. Evans. Jour. Ent. Res. *24*: 349. 1933.
"A Simple Method of Collecting Thrips and Other Insects from Blossom."

V. MISCELLANEOUS.

133. A. E. V. Richardson. C.S.I.R. Jour. *1*: 27. 1928.
"The Commonwealth and Agricultural Research."
A survey of the function of the Commonwealth in relation to agricultural research.

134. A. E. V. Richardson. C.S.I.R. Jour. *1*: 154. 1928.
"The Imperial Agricultural Research Conference, 1927."
A summary of the work and decisions of the Imperial Agricultural Research Conference.

135. A. E. V. Richardson. Economic Record *4*: 249. 1928.
"The Application of Economic Research to the Agricultural Industries."
A discussion of the scope and methods of economic research in relation to agriculture, with special reference to farm surveys and the costs of production of farm commodities.

136. A. E. V. Richardson. Jour. Agric. Sth. Aust. *32*: 522. 1928.
Investigational work in progress at the Waite Institute.

137. A. E. V. Richardson. Queens. Agric. Jour. *34*: 18. 1931.
"The Application of Science to Agriculture."
Address delivered to the Australian and New Zealand Association for the Advancement of Science, Brisbane, 1930.

138. J. A. Prescott. Trans. Roy. Soc. Sth. Aust. *55*: 65. 1931.
"Atmospheric Saturation Deficit in Australia."
From revised data for mean annual temperature and mean relative humidity, saturation deficit values are calculated for Australian stations. A map is presented giving isobars of this value ranging from 0·1 inch to 0·6 inch of mercury.

139. K. M. Fraser. C.S.I.R. Jour. *4*: 204. 1931.
"The Rate of Growth of a South Australian Merino Fleece."
The results of fifteen monthly measurements of the wool staples of Merino sheep of uniform age, weight and quality at a fixed point on the sheep, namely, the acromion process at the inferior end of the spine of the scapula, showed that the rate of growth of the staple was uniform.

140. A. E. V. Richardson. Bailliere's Encyclopaedia of Scientific Agriculture *1* : 14. 1931.

A discussion of the topography, climate and vegetation of Australia, the distribution and development of the agricultural and pastoral industries, the part played by scientific research in their development, and the organization of research and extension work in agriculture in Australia.

141. A. E. V. Richardson. Annals of the American Academy of Political and Social Science, *158* : 251.

A survey of the organization and progress of agricultural research in Australia.

Meteorological Records, 1925-1932

Since the inception of the work of the Institute in 1925, daily records of rainfall, barometric pressure, maximum and minimum air temperature, atmospheric humidity, number of hours of bright sunshine, evaporation from a free water surface, and maximum and minimum soil temperatures at 1 inch, 6 inches, 12 inches, and 24 inches have been recorded. In addition, continuous records of air temperatures, atmospheric humidity, and soil temperatures have been taken.

In 1930 a self-recording anemometer, based on the Halliwell-Dines principle, was installed, and continuous records of the direction and velocity of the wind have been obtained.

Rainfall.

Rainfall and its incidence are controlling factors in crop production. The average annual rainfall for eight years, 1925-32 at the Waite Institute is 23·9 inches. The average annual rainfall for 94 years for Adelaide (four miles distant) is 21·1 inches. For the 1925-32 period the average rainfall at Adelaide was 20·5 inches.

A feature of the rainfall is its marked winter incidence. Approximately 77 per cent. of the annual precipitation occurs within the period of growth for cereals, May 1 to November 30. The summer months are characterized by hot, dry weather, low rainfall, and high rate of evaporation.

The climate is essentially of the Mediterranean type, with winter rainfall and summer drought. The dry period of summer and early autumn normally terminates early in May with a pronounced "break" in the weather. Antarctic rain systems set in in May, and continue more or less regularly till August. During this period the soil temperatures are low, but they never fall for any extended period below the temperature at which the growth of cereals is inhibited.

The rainfall averages $2\frac{3}{4}$ inches to 3 inches per month throughout the winter months, and the subsoil usually becomes thoroughly moist to an average depth of at least four feet. The growth of cereals proceeds slowly, and tillering is active during this period. Towards the end of August the air and soil temperatures rise substantially, and cereal crops and pastures make rapid growth. Transpiration becomes active, and as the crop approaches the stage of ear production (September-October) the rate of transpiration increases rapidly. The moisture supply of the soil begins to fall off rapidly with the increasing demands of the crop. During the period of earing the transpiration rate is often accelerated temporarily by hot northerly winds, which precede the easterly advance of the anti-cyclones.

Substantial rains in September or October are normally necessary for the production of heavy crops. A shortage of rainfall in these months leads to rapid deterioration of the crop, owing to rapid transpiration, brought about by a combination of high air temperatures and low atmospheric humidity. The growing crop adjusts itself to the environmental conditions by reducing the number of ear-bearing tillers. Cool weather experienced during this critical period, or during the ripening processes, materially lowers the transpiration rate and results in improved crop yields.

The harvesting period (December-January) synchronizes with hot, dry weather, which facilitates the harvesting of cereals, and enables grain of low moisture content and high quality to be produced.

The monthly rainfall for eight years is summarized below.

Mean Monthly Rainfall for Eight Years, 1925-32, Waite Institute.

Month.	1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	Monthly average for 8 yrs.
January	0·570	—	0·245	1·095	0·675	0·035	0·762	0·227	0·451
February	3·160	1·080	1·088	2·630	0·027	0·363	0·270	1·604	1·278
March	0·375	0·015	1·152	1·365	0·249	0·048	1·725	1·637	0·821
April	1·159	1·832	0·421	1·356	0·653	1·016	1·059	5·510	1·626
May	5·113	6·270	3·307	2·650	1·728	0·970	3·252	2·114	3·176
June	2·203	2·141	2·534	4·584	4·263	1·522	5·968	5·272	3·561
July	3·139	2·293	3·512	3·332	2·649	4·898	4·173	3·527	3·440
August	1·837	4·714	4·121	0·845	2·373	3·729	3·265	3·615	3·062
September	3·764	2·765	1·168	2·039	2·720	3·214	4·512	1·942	2·766
October	1·195	1·910	0·408	2·968	1·168	3·350	0·632	2·427	1·757
November	0·470	0·788	1·419	0·535	1·263	1·122	1·073	0·558	0·904
December	0·140	1·966	1·625	0·145	3·677	0·917	0·206	0·401	1·135
Total	23·125	25·774	21·000	23·544	21·445	21·184	26·897	28·834	23·975

Evaporation.

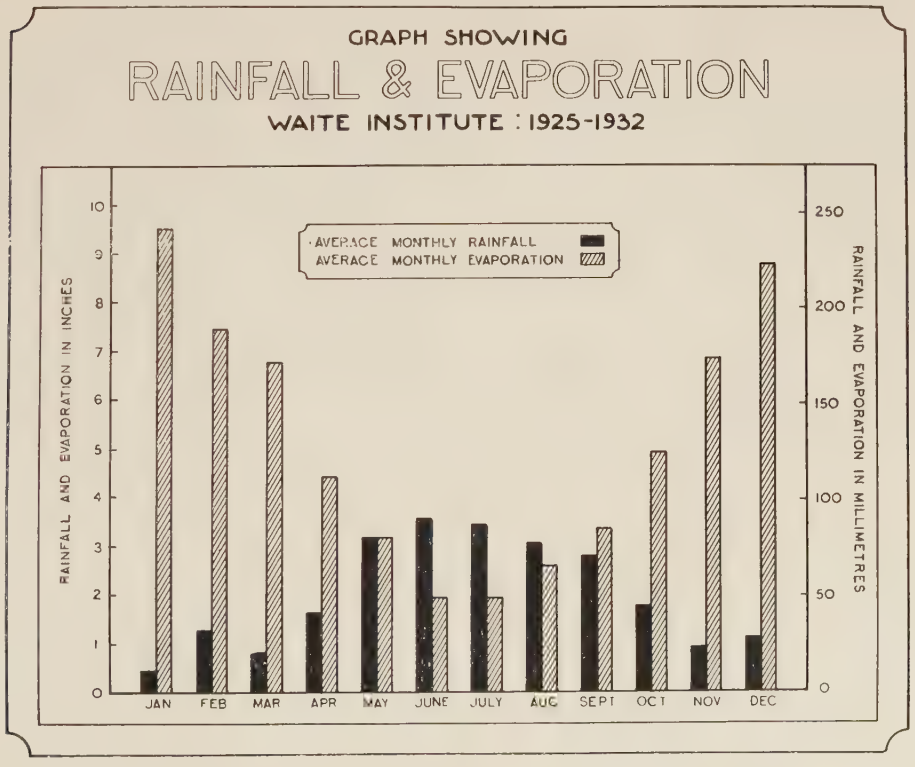
The evaporation rate is measured by the amount of loss of water from a freely exposed water-surface at ground level. The apparatus used is a standard evaporimeter, 3 feet in diameter and 3 feet deep, enclosed within a cylindrical tank, 4 feet in diameter and 3 feet deep. Both tanks are sunk to ground level and filled within 2 inches of the surface. The evaporation is measured by the fall of the surface level of the water in the inner tank. A large glass float attached to a brass rod registers the surface level of the water, and a vernier attachment enables the fall of the water surface to be recorded to the nearest 1/1000th of an inch.

A summary of the monthly evaporation from a free water surface for eight years, 1925-1932, is given below.

Monthly evaporation rate from a free water surface, Waite Institute, 1925-1932.

Month.	1925. inches.	1926. inches.	1927. inches.	1928. inches.	1929. inches.	1930. inches.	1931. inches.	1932. inches.	Monthly average. 1925-32. inches.	Daily evaporation. inches.
January	8·910	9·594	9·276	8·700	8·343	10·479	9·443	11·519	9·533	·308
February	6·109	8·129	6·838	7·692	7·683	8·924	7·998	6·239	7·452	·264
March	6·773	7·816	6·288	6·014	6·314	7·487	6·539	6·884	6·764	·218
April	3·791	5·140	4·011	4·650	4·628	5·447	4·497	3·077	4·405	·147
May	2·687	2·898	3·245	3·960	3·312	3·491	2·615	3·207	3·177	·102
June	1·504	1·824	2·458	1·549	2·225	2·299	1·602	2·049	1·939	·065
July	1·568	1·922	1·852	2·603	2·252	1·889	1·558	1·811	1·932	·062
August	2·051	2·601	2·557	2·854	3·028	2·514	2·664	2·396	2·583	·083
September	2·805	3·411	3·240	3·772	3·539	3·534	3·344	3·282	3·366	·112
October	4·656	4·724	5·092	4·172	4·972	5·408	5·692	4·486	4·900	·158
November	6·222	7·102	7·135	7·225	6·344	7·323	6·880	6·490	6·840	·228
December	8·592	8·005	9·264	9·239	6·890	8·783	10·169	9·082	8·753	·282
Total	55·668	63·166	61·256	62·430	59·530	67·578	63·001	60·522	61·644	·169

The mean annual evaporation from a free water surface is 61·6 inches per annum. During the period of crop growth (May to November inclusive) the evaporation is 24·73 inches, or 40 per cent. of the annual evaporation.



Mean monthly rainfall and evaporation at the Waite Institute. 1925-1932.

The average evaporation rate is an important factor in determining the efficiency of the rainfall for crop production, mainly because of the close correlation that has been shown to exist between the rate of transpiration from the crop and the rate of evaporation from a free water surface. The rate of evaporation may be regarded as an expression of the sum of the environmental factors —radiation intensity, air temperature, wet bulb depression, and wind velocity —all of which influence the rate of transpiration of the crop.

Whilst the ratio, annual evaporation to annual rainfall, is 2·6 to 1, the ratio of evaporation to rainfall for the normal period of crop growth is less than 1·2 to 1. The mean monthly rainfall and evaporation rate are shown graphically in the accompanying graph. From May to September the mean rainfall exceeds the total evaporation from a free water surface, and the conditions for the growth of pastures and cereals are very favourable. During October and November, however, the mean evaporation rate is $4\frac{3}{4}$ times greater than the mean rainfall for these months. This high ratio of evaporation to rainfall at the critical period of development of the cereal crop is the main limiting factor to heavy crop yields.

Air Temperatures.

Mean air temperature is an important factor in determining the climate of a region. Plant life is constantly under the influence of the temperature of the air near the surface of the earth. The mean air temperature and its daily and seasonal fluctuations during the rainy season largely determine the types of crop that can be grown under given soil and rainfall conditions.

The air temperatures are obtained from standard maximum and minimum thermometers shielded from the direct rays of the sun in a standard meteorological screen in such a manner as not to obstruct atmospheric circulation. The significance of the mean daily air temperature depends upon the amplitude of the periodic daily range and the nature of the variations from day to day. The daily minimum temperature usually occurs immediately prior to sunrise, and the daily maximum between 2 and 3 p.m. The average of the daily maximum and minimum for each month gives the mean monthly maxima and minima.

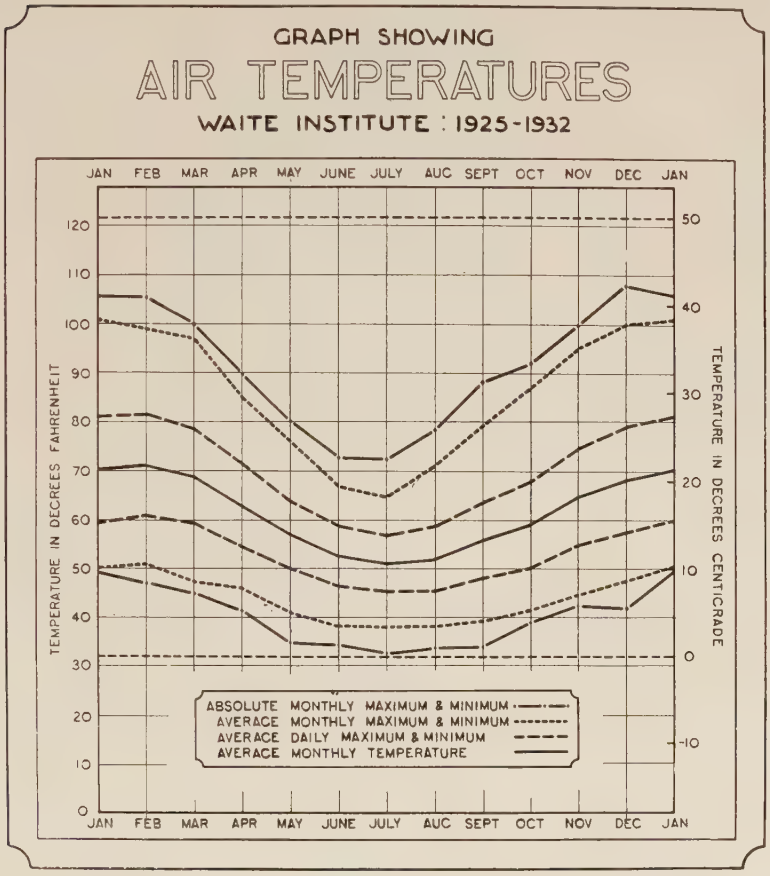
The significance of the mean monthly temperature depends upon the extent of the periodic variation in the daily values from which it is derived, and the extent of the accidental fluctuations that occur during the month. In addition to the average of the daily maxima, and the average of the daily minima, it is important to know the mean of the monthly extremes and the absolute maximum for each month. These data are summarized in the accompanying graph, which shows for a period of eight years, 1925-32, the following values:

(a) The mean monthly air temperature in degrees Fahrenheit and Centigrade.

(b) The mean daily maximum and mean daily minimum air temperatures.

(c) The mean monthly maximum and minimum air temperatures, i.e. the mean of the highest and lowest temperatures recorded each month.

(d) The absolute monthly maximum and minimum air temperatures, or the highest or lowest temperatures ever recorded in each month.



Absolute and mean monthly and daily air temperatures. Waite Institute. 1925-1932.

The vertical distance between the lines showing the mean daily maxima and minima represents the average daily range in temperature for each month. Similarly, the distance between the lines showing the mean monthly maxima and minima shows the average monthly range, whilst the distance between the absolute monthly maxima and minima shows the extent of the range in absolute monthly temperatures.

The mean air temperature during the growing period of the crop (May-November) is 55·9°F., or 13·2°C. The mean monthly maximum and minimum air temperatures during this period are respectively 63·3°F. and 48·5°F.

Mean Monthly Maximum and Minimum Air Temperatures for Eight Years, 1925-1932, Waite Institute.

	1925. Max. °F	1925. Min. °F	1926. Max. °F	1926. Min. °F	1927. Max. °F	1927. Min. °F	1928. Max. °F	1928. Min. °F	1929. Max. °F	1929. Min. °F	1930. Max. °F	1930. Min. °F	1931. Max. °F	1931. Min. °F	1932. Max. °F	1932. Min. °F	Average 1925-32. Max. °F	Average 1925-32. Min. °F
January	79·2	57·9	80·8	58·1	84·7	60·5	78·8	59·4	78·7	59·2	80·6	59·4	78·3	58·4	87·8	64·4	81·1	59·6
February	78·6	59·3	85·6	61·3	78·3	58·3	78·9	58·8	87·5	66·6	88·5	65·8	79·9	58·1	75·4	57·0	81·5	60·6
March	80·5	59·6	81·2	59·1	76·6	57·5	78·3	59·2	75·6	58·2	81·1	61·8	75·8	57·6	77·1	60·1	78·2	59·1
April	72·8	53·9	71·5	55·1	68·8	52·4	80·1	57·3	70·0	53·5	72·0	55·8	69·6	53·5	66·4	54·2	71·4	54·4
May	64·5	50·4	59·9	46·5	63·3	47·8	62·8	49·2	63·9	49·9	66·4	51·9	62·6	51·9	66·4	53·0	63·7	50·0
June	59·9	47·0	58·6	47·6	57·9	44·3	58·2	45·9	58·8	45·7	59·8	45·5	56·7	46·2	57·7	47·5	58·4	46·2
July	56·3	45·2	59·1	44·9	56·6	43·9	58·1	46·4	54·2	43·0	58·6	48·4	55·2	44·5	56·7	45·5	56·8	45·2
August	58·6	43·7	58·1	44·8	58·2	45·9	62·6	46·8	57·8	43·9	58·5	46·2	57·7	45·0	58·3	45·7	58·6	45·2
September	59·8	46·4	65·5	49·6	65·1	47·7	65·7	49·6	62·6	47·1	63·2	48·1	62·6	47·5	63·7	48·4	63·5	48·0
October	68·1	48·9	68·7	49·2	71·4	52·6	64·9	48·9	67·2	49·4	71·8	54·8	66·9	48·6	63·3	48·3	67·7	50·0
November	76·6	55·1	75·1	54·4	77·8	59·5	75·3	54·6	71·6	51·5	74·0	54·8	73·1	55·2	73·9	54·7	74·6	54·9
December	79·7	55·7	77·5	55·8	79·4	58·2	81·3	59·4	73·7	54·3	81·7	61·3	83·1	59·5	75·8	55·5	79·0	57·4
Mean	69·6	51·9	70·1	52·2	69·8	52·4	70·4	53·0	68·5	51·9	71·4	54·5	68·5	52·2	68·5	52·9	69·5	52·6

Soil Temperatures.

The maximum and minimum soil temperatures are recorded at 1 inch, 6 inches, 12 inches, and 24 inches under the surface of the land kept in fallow. Records of soil temperature in the surface layers of soil are of considerable importance in studying the biological activities of the soil, particularly the process of nitrification and the relationship of temperature to such activities. The records are taken by Negretti & Zambra self-recording soil thermometers, which give continuous records of the fluctuations in soil temperature.

The mean monthly maximum and minimum soil temperatures for eight years are summarized in the following table.

Mean Monthly Soil Temperatures at 1 inch, 6 inches, 12 inches, 24 inches, for Eight Years, 1925-1932, Waite Institute.

	At 1 inch.		At 6 inches.		At 12 inches.		At 24 inches.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	112·1	64·4	85·8	73·1	78·3	72·2	76·6	71·3
February	106·8	64·1	84·2	72·0	77·2	71·2	76·8	71·8
March	101·3	61·3	79·9	69·1	74·4	68·7	75·1	70·0
April	84·9	55·4	70·1	61·5	67·0	62·4	69·7	64·6
May	71·0	50·1	60·9	54·1	59·8	55·9	63·1	59·0
June	63·8	47·3	55·8	50·6	54·7	51·2	57·4	54·1
July	61·4	46·4	53·9	49·3	52·8	49·2	55·2	52·0
August	65·2	47·1	56·4	51·0	53·6	49·7	55·4	51·7
September	73·7	50·5	62·4	55·0	58·2	53·6	58·7	54·6
October	83·6	54·1	68·6	59·3	63·1	57·9	63·1	58·7
November	98·1	59·7	77·7	65·6	70·3	64·6	69·1	64·3
December	108·1	63·0	83·0	70·3	75·3	69·2	73·8	68·8

The march of soil temperature is determined primarily by solar radiation. At depth, the soil for all practical purposes has a constant temperature. The surface layers, however, show wide daily, monthly, and annual fluctuations. The surface layer of soil (1 inch) shows considerable fluctuations in temperature, since during the day a considerable amount of radiant heat is received from the sun, and during the night the surface layers of soil lose heat rapidly by radiation.

Records show that during a typical week during midsummer (20/1/30) the temperature of the surface 1 inch of soil gave a daily fluctuation of 50°F. to 60°F. At 6 inches deep the daily fluctuation was 10–14°F. during the same period. During a typical week in midwinter (22/7/29) the daily fluctuation at 1 inch did not exceed 18°F., and at 6 inches the daily variation was less than 6°F.

The mean monthly minimum soil temperature does not at any period of the year fall below the temperature at which germination or growth of cereals is inhibited (41°F.).

The time of the maximum soil temperature varies with the depth. At the

soil surface the time of maximum temperature is, on clear days, determined by the time at which the sun is on the meridian. Since this is practically constant throughout the year, the time at which the maximum temperature of the surface soil is reached is also constant. The temperature wave is transmitted by conduction from the surface layer to the successive soil layers below the surface. The rate of conduction is slow, hence the time of maximum temperature at the lower layers will show a lag behind that of the maximum temperature at the surface.

Throughout the year, on clear days, when radiation intensity is at a maximum, the maximum temperature of the soil at 1 inch deep is reached at about 1.30 p.m., whilst air temperatures recorded in an adjacent meteorological screen reach a maximum between 2.30 and 3 p.m. The maximum temperature of the soil at a depth of 6 inches below the surface occurs at approximately 5.30 p.m.

On the other hand, the time of minimum soil temperature varies with the season. The minimum at the surface of the soil is reached normally just before sunrise, i.e. just before solar radiation begins to affect air and soil temperatures. The actual time of this minimum soil temperature will depend upon the time of sunrise. Since the time of the minimum soil temperature at the surface varies, so the time of the minimum soil temperature below the surface will vary.

During January the minimum temperature at 1 inch occurs at 5 a.m., and at 6 inches about 8 to 8.30 p.m. During July the minimum temperature at 1 inch is reached at 7.30 a.m., and at 6 inches shortly after 10 a.m.

The maximum temperature of the surface of the soil is invariably higher than that of the maximum air temperature. The differences between the maximum air temperature and the maximum temperature at the surface of the soil are much less marked in winter than in summer.

The mean monthly amplitude of the daily temperature waves in soil and air for eight years is summarized in the following table:

Monthly Means of Amplitudes of daily temperature waves in the Soil and Air, Waite Institute, 1925-1932.

Month	Soil Temperatures. 1 inch.	6 inches.	24 inches.	Air.
January ..	47·7	12·7	5·3	21·5
February ..	42·7	12·2	5·0	20·9
March ..	40·0	10·8	5·1	19·1
April ..	29·5	8·6	5·1	17·0
May ..	20·9	6·8	4·1	13·7
June ..	16·5	5·2	3·3	12·2
July ..	15·0	4·6	3·2	11·6
August ..	18·1	5·4	3·7	13·4
September ..	23·2	7·4	4·1	15·5
October ..	29·5	9·3	4·4	17·7
November ..	38·4	12·1	4·8	19·7
December ..	45·1	12·7	5·0	21·6

The amplitude of the daily temperature waves in soil varies according to season and depth. Thus for January the mean daily variation in soil temperature at 1 inch is 47·7°F., at 6 inches 12·7°F., and at 24 inches 5·3°F. In July the mean daily variation is only 15·0°F. at 1 inch, 4·6°F. at 6 inches, and 3·2°F. at 24 inches. The amplitude of the daily temperature wave in air is for January 21·5°F., and for July 11·6°F.

It will be noted that during the winter months the mean minimum soil temperature increases from 1 inch to 24 inches. At a depth of 24 inches the minimum soil temperature exceeds 51°F. throughout the winter months, whilst the minimum soil temperature at 1 inch falls to 46·4°F. during July. This probably explains why early sown cereal crops under favourable conditions of moisture supply frequently make such vigorous, rank growth during the winter months as to necessitate feeding down by stock. The root systems of early sown crops become well established in the subsoil, and the higher soil temperatures of the lower layers are favourable for active growth.

Number of Hours of Bright Sunshine.

The number of hours of bright sunshine is recorded daily by means of a Campbell-Stokes sunshine recorder. The number of hours of bright sunshine per month and per day are summarized in the following table.

Mean number of hours of bright sunshine per month and per day for eight years, 1925-1932, Waite Institute.

Month.	Number of hours per day.	Number of hours per month.
January	9·4	291
February	8·5	238
March	7·3	226
April	5·8	174
May	4·3	133
June	3·5	105
July	3·3	102
August	4·5	140
September	5·6	168
October	6·7	208
November	8·4	252
December	9·0	279
	6·4	2,316

The total number of bright sunshine hours per annum is 2,316, or a daily average throughout the year of 6·4.

Wind Velocity.

Continuous records both of the velocity of the wind and its direction have been registered by a self-recording anemometer since 1931. The average daily

maximum wind velocity and the daily average velocity in miles per hour during each month of 1931-32 are summarized below.

Average daily maximum and daily average wind velocity (in miles per hour) for two years, 1931-1932, Waite Institute.

	1931.		1932.			
	Average Daily Max.	Daily Average.	Average Daily Max.	Daily Average.	Average for 2 years. Daily Max.	Daily Av.
January ..	23	6·0	26	5·0	24·5	5·5
February ..	24	5·4	23	3·9	23·5	4·6
March ..	21	4·1	24	4·2	22·5	4·1
April ..	18	3·0	19	3·5	18·5	3·3
May ..	20	3·7	17	2·1	18·5	2·9
June ..	19	4·1	16	2·6	17·5	3·3
July ..	15	2·9	18	2·4	16·5	2·7
August ..	13	3·4	25	4·1	19·0	3·7
September ..	20	4·6	19	2·3	19·5	3·5
October ..	23	4·8	23	4·4	23·0	4·6
November ..	25	4·7	22	4·1	23·5	4·4
December ..	25	4·8	23	4·3	24·0	4·5
	20·5	4·3	21·2	3·5	20·8	3·9

Records of Field Experimental Work
1925-32

Records of Field Experimental Work, 1925-32

NOTE ON THE SOIL OF THE EXPERIMENTAL FIELD.

The surface (0–4 inches) soil of the area on which the major part of the experimental work has been conducted is a brown loam moderately high in silt and in fine sand, and containing a small amount of calcium carbonate. It becomes slightly heavier between 4–9 inches, though essentially the same in type. The immediate subsoil is a light red-brown medium clay, showing a sharp increase in clay content to 47 per cent., again with only a trace of calcium carbonate.

Increasing clay content and heavier texture occur to 3 feet, at which there is a reversion to a light clay, with a definite rise in calcium carbonate to approximately 4 per cent.

The reaction is weakly acid at the surface, becoming approximately neutral in the heavy clay horizon, and rising to above pH 8 with the advent of calcium carbonate. The mechanical analysis, description, and some chemical data of a profile are included in the following table.

Sample No. Depth in inches.	U151 0–4	U152 4–9	U153 9–18	U154 18–27	U155 27–36	U156 36–45	U157 45–54
Coarse sand	2·1	1·9	1·2	0·7	0·6	0·8	1·3
Fine sand	43·7	40·8	26·3	18·6	19·2	24·5	25·3
Silt	34·8	33·8	22·8	18·8	19·3	28·4	29·7
Clay	18·0	21·8	47·4	59·9	59·2	40·7	37·2
Loss on acid treatment	1·0	0·7	1·1	1·4	1·6	6·3	5·2
Moisture	0·4	0·6	1·2	2·0	1·7	1·2	1·1
Loss on ignition	4·4	4·1	6·2	7·3	7·2	7·3	6·7
$CaCO_3$	0·03	Trace	0·01	—	0·13	4·8	4·0
Nitrogen	0·10	0·09	0·08	0·08	0·07	0·05	0·04
Reaction pH	5·9	5·9	6·4	6·4	6·9	8·2	8·3
Soil Description	Brown loam	Brown loam to clay loam	Light red brown medium clay	Red brown heavy clay	Brown heavy clay	Brown light clay	Brown light clay

Site of soil profile: Nitrogen experiments, 1930.

SUMMARY OF FIELD EXPERIMENTS.

1. Permanent rotation tests, 1926-1932.
2. Permanent manurial tests, 1926-1932.
3. The effect of sulphate of ammonia on wheat:
   (1) After bare fallow, (2) after stubble, 1928-1932.
4. The effect of equivalent dressings of nitrogen in various forms of fertilizer on wheat, 1928-1932.
5. Cultural tests with various quantities of superphosphate applied to wheat, 1927-1932.
6. The comparative effects of drilling and broadcasting phosphatic and nitrogenous manures.
7. The effect of phosphates, nitrogen, and phosphates plus nitrogen on wheat grown in various rotations.
8. The effect of dressings of various quantities of superphosphate and sulphate of ammonia alone and in various combinations on wheat.
9. The effect of sulphate of ammonia on barley.
10. Uniformity trials with cereals and with natural pasture:
    (1) 1925—Wheat, barley, oats.
    (2) 1927—Wheat.
    (3) 1929—Wheat, barley, oats, peas.
    (4) 1928—Natural pasture.
11. Top-dressing of natural pastures with equivalent quantities of various forms of phosphate, 1925-1932.
12. The effect of sulphate of ammonia on a typical subterranean clover sward with regard to (a) the carrying capacity in cow-days, (b) the establishment of surface-sown rye-grass; Mount Barker, 1930-1932.
13. The effect of sulphate of ammonia on the yield and botanical composition of a seeded pasture mixture under various systems of pasture management, Waite Institute, 1930-1932.
14. Investigations on irrigated pastures:
    (1) The yield and botanical composition of an irrigated permanent pasture grazed by sheep at 28-day intervals, Wood's Point.
    (2) Yields of pasture (a) grazed by sheep, (b) mown at intervals of 28 days.
    (3) Yields of pasture when mown at intervals of 28 and 56 days.
    (4) The phosphoric acid and nitrogen content of a pasture (a) rotationally grazed by sheep every 28 days, (b) mown every 28 days, (c) mown every 56 days.

PERMANENT ROTATION TESTS.

Objective:

To determine the yield of wheat when grown under different systems of crop rotation.

Technique:

(1) Thirty-one plots, grouped in 12 rotations, with wheat grown in each rotation every year.

(2) Size of each plot = 0·144 acre.

(3) Basal manurial dressing with each sown crop 20 lb. P_2O_5 per acre 1925-1928, 40 lb. P_2O_5 (= 187 lb. super), 1929-1932.

(4) Varieties of crop: wheat, Sepoy; oats, Early Burt; barley, Pryor; peas, Brunswick White; pasture, Wimmera rye-grass.

Mean Yields for Seasons 1926-1932.

Crop Rotation.	Wheat. (bush. per ac.)	Oats. (bush. per ac.)	Barley. (bush. per ac.)	Peas. (bush. per ac.)	Temporary Pasture. (cwts. per ac. of dry hay)
1. Wheat, bare fallow	35·34	—	—	—	—
2. Wheat, peas	33·06	—	—	18·40	—
3. Wheat, pasture, bare fallow	37·65	-	—	—	36·14
4. Wheat, oats, bare fallow	36·28	63·26	—	—	—
5. Wheat, peas, bare fallow	36·66	—	—	26·42	—
6. Wheat, barley, bare fallow	37·34	—	60·12	—	—
7. Wheat continuously	21·48	—	—	—	—
8. Wheat, oats, peas	36·58	53·79	—	24·80	—
9. Wheat, barley, peas	37·51	—	56·90	25·59	—
10. Wheat, oats, pasture, bare fallow	41·22	66·62	—	—	41·22
11. Wheat, Sudan Grass	38·77	—	—	—	17·53
12. Wheat, bare fallow	38·05	—	—	—	—

PERMANENT MANURIAL TESTS.

Objective:

To determine the effect of various fertilizers on the yield of wheat, oats, and barley.

Technique:

(1) Plots not replicated, but each group sown in duplicate from 1929 onwards with six unmanured controls.

(2) Size of each plot = 1/30th acre.

(3) Wheat sown on fallow 1927-29, peas 1930, barley stubble 1931, fallow 1932.

(4) Oats sown on fallow 1927-28, and wheat or barley stubble in other years.

(5) Barley sown on oats or wheat stubble.

Mean Yields Seasons 1926-1932.

Dressing of fertilizer per acre.	Wheat. bush. per ac.	Oats. bush. per ac.	Barley. bush. per ac.
1. Effect of Superphosphate:			
No manure	26·25	54·36	38·52
10 lb. P_2O_5 (47 lb. super)	34·05	59·67	49·67
20 lb. P_2O_5 (94 lb. super)	36·32	60·52	53·31
30 lb. P_2O_5 (140 lb. super)	37·85	61·52	55·35
40 lb. P_2O_5 (187 lb. super)	38·56	59·73	56·97
60 lb. P_2O_5 (280 lb. super)	38·86	61·13	57·96
2. Equivalent Dressings of Phosphate:			
No manure	26·25	54·36	38·52
Superphosphate, 94 lb. (= 20 lb. P_2O_5)	36·32	60·52	53·31
Basic Slag, 129 lb. (= 20 lb. P_2O_5)	36·43	59·06	53·23
Bonedust, 109 lb. (=20 lb. P_2O_5)	32·47	58·86	48·57
3. Lime as a Supplement:			
Superphosphate, 94 lb. (= 20 lb. P_2O_5)	36·32	60·52	53·31
Superphosphate, 94 lb. (20 lb. P_2O_5) + lime, 20 cwt. every 4 years	40·30	60·89	60·51
4. Nitrogen:			
Superphosphate, 94 lb. (= 20 lb. P_2O_5)	36·32	60·52	53·31
Superphosphate, 94 lb. (= 20 lb. P_2O_5) + nitrate of soda, 78 lb. (= $12\frac{1}{2}$ lb. N)	37·93	64·33	58·12
Superphosphate, 94 lb. (= 20 lb. P_2O_5) + sulphate of ammonia, 60 lb. (= $12\frac{1}{2}$ lb. N)	38·47	62·21	58·12

SULPHATE OF AMMONIA ON WHEAT AFTER STUBBLE AND AFTER FALLOW.

Treatments:

A. No nitrogen.
B. Sulphate of ammonia, ½ cwt. at seeding.
C. Sulphate of ammonia, 1 cwt. at seeding.
D. Sulphate of ammonia, 2 cwt. at seeding.
E. Sulphate of ammonia, 1 cwt. in spring.
F. Sulphate of ammonia, 1 cwt. at seeding and 1 cwt. in spring.

Technique:

a. Thirty-six plots, each 1/25th acre, after fallow and 36 after stubble.
b. Six treatments with six replications in the form of a Latin square.
c. Basal dressing of 288 lb. superphosphate applied at seeding to all wheat plots in year of the test.
d. Samples for soil moisture and nitrate nitrogen taken on no nitrogen plots after stubble and fallow.

Effect of Various Quantities of Sulphate of Ammonia on Yield of Wheat (Total Produce and Grain) when grown after (a) Bare Fallow, (b) a Wheaten Stubble (Stubble-ploughed Land), Waite Institute, 1928-1932.

Total Produce (cwt. per acre).

Quantities of Sulphate of Ammonia.	1928.	1929.	1930.	1931.	1932.	Mean 1928–32.	Mean increase due to Nitrogen.
Grown after Stubble:							
A. No nitrogen ..	65·0	39·4	37·7	36·5	59·11	47·5	—
B. ½ cwt. at seeding	66·3	42·5	45·1	44·0	65·51	52·7	5·2
C. 1 cwt. at seeding	67·4	43·8	50·2	51·9	73·76	57·4	9·9
D. 2 cwt. at seeding	72·1	49·6	59·4	62·5	89·09	66·5	19·0
E. 1 cwt. in spring	66·8	41·5	48·4	44·1	74·86	55·1	7·6
F. 1 cwt. at seeding, 1 cwt. in spring	69·2	49·1	58·4	60·6	86·48	64·8	17·3
Grown after Fallow:							
A. No nitrogen ..	65·5	90·5	68·8	47·4	79·39	70·3	—
B. ½ cwt. at seeding	65·7	92·7	70·4	53·3	84·38	73·3	3·0
C. 1 cwt. at seeding	65·5	91·8	69·4	56·9	87·70	74·3	4·0
D. 2 cwt. at seeding	65·3	91·8	67·9	60·3	93·94	75·8	5·5
E. 1 cwt. in spring	65·0	91·8	69·3	51·8	87·28	73·0	2·7
F. 1 cwt. at seeding, 1 cwt. in spring	64·8	90·8	68·7	59·4	92·50	75·2	4·9

SULPHATE OF AMMONIA ON WHEAT AFTER STUBBLE AND AFTER FALLOW.

Effect of Various Quantities of Sulphate of Ammonia on Yield of Wheat when grown after (a) Bare Fallow, (b) a Wheaten Stubble (Stubble-ploughed Land), Waite Institute, 1928-1932.

Grain (bushels per acre).

Quantities of Sulphate of Ammonia.	1928.	1929.	1930.	1931.	1932.	Mean 1928–32.	Mean increase due to Nitrogen.
Grown after Stubble:							
A. No nitrogen ..	48·53	30·55	29·35	31·88	42·50	36·56*	—
B. ½ cwt. at seeding	48·00	33·54	33·86	36·65	46·55	39·72*	3·16
C. 1 cwt. at seeding	48·05	33·85	37·18	40·47	50·22	41·95*	5·39
D. 2 cwt. at seeding	51·30	37·26	42·56	43·59	53·76	45·69*	9·13
E. 1 cwt. in spring	47·35	32·48	35·76	36·32	50·60	40·50*	3·94
F. 1 cwt at seeding, 1 cwt. in spring	49·01	36·94	41·85	43·62	53·95	45·07*	8·51
Grown after Fallow:							
A. No nitrogen ..	47·25	65·27	45·60	38·70	48·63	49·09†	—
B. ½ cwt. at seeding	47·61	65·76	45·73	42·84	50·97	50·58†	1·49
C. 1 cwt. at seeding	46·67	65·34	43·71	44·36	52·25	50·47†	1·38
D. 2 cwt. at seeding	46·02	64·65	42·21	44·95	51·04	49·77†	0·68
E. 1 cwt. in spring	45·94	64·78	43·66	41·69	51·21	49·46†	0·37
F. 1 cwt. at seeding, 1 cwt. in spring	45·46	63·53	41·21	44·52	51·70	49·28†	0·19

*Statistical analysis shows that the value of z for treatments is significant. The standard error of the difference between these mean values for 1928-32 is 1·47 bushels.

†Statistical analysis shows that the value of z for treatments is significant. The standard error of the difference between these mean values for 1928-32 is 1·03 bushels.

EQUIVALENT DRESSINGS OF NITROGEN ON WHEAT.

Treatments:

Nitrogenous fertilizers applied at the rate of 23 lb. nitrogen per acre.

A. No nitrogen.
B. Nitrate of soda, 150 lb. per acre.
C. Sulphate of ammonia, 112 lb. per acre.
D. Nitro-chalk, 150 lb. per acre.
E. Urea, 50 lb. per acre.
F. Diammonium phosphate, 112 lb. per acre.

Technique:

a. Thirty-six plots, each 1/25th acre, consisting of six treatments and six replications randomized in the form of a Latin square.
b. Basal dressing of 288 lb. of superphosphate applied to all plots except those receiving diammonium phosphate.
c. Diammonium phosphate broadcast on surface after seeding in 1928, before seeding in 1929, and drilled in with seed in subsequent years.
d. Plots sown on land ploughed from natural pasture in 1928 and from land previously cropped with wheat in subsequent years.

Effect of Equivalent Quantities of Nitrogen (23·4 lb. per acre) applied in the form of Nitrate of Soda, Sulphate of Ammonia, Nitro-chalk, Urea and Diammonium Phosphate, on the Yield of Wheat (Total Produce and Grain) after Pasture or Wheat, Waite Institute, 1928-32.

Total Produce (cwt. per acre).

Treatments. Nitrogen fertilizer at rate of 23·4 lb. Nitrogen per acre.	Wheat after Pasture. 1928.	Wheat after Wheat. 1929.	Wheat after Wheat. 1930.	Wheat after Wheat. 1931.	Wheat after Wheat. 1932.	Mean. 1928–32.	Mean increase due to Nitrogen.
A. No nitrogen ..	35·7	30·8	38·3	33·08	27·20	33·02	—
B. Nitrate of soda ..	44·4	36·8	50·6	50·94	44·74	45·50	12·48
C. Sulphate of ammonia	42·8	35·3	49·7	49·16	36·41	42·67	9·65
D. Nitro-chalk ..	42·4	37·0	48·5	49·90	38·95	43·35	10·33
E. Urea	42·8	36·1	47·3	47·13	36·68	42·00	8·98
F. Diammonium phos. .	32·0	31·4	48·5	43·75	40·49	39·23	6·21

Grain (bushels per acre).

A. No nitrogen ..	29·35	26·35	32·01	29·67	22·57	27·99*	—
B. Nitrate of soda ..	34·48	31·49	40·05	40·27	31·83	35·62*	7·63
C. Sulphate of ammonia	33·67	29·68	39·51	38·63	27·37	33·77*	5·78
D. Nitro-chalk	33·11	30·90	38·59	39·33	28·68	34·12*	6·13
E. Urea	33·86	29·65	37·29	37·55	27·35	33·14*	5·15
F. Diammonium phos. .	25·52	26·52	38·31	33·91	29·85	30·82*	2·83

*Statistical analysis shows that the value of z for treatments is significant. The standard error of the difference between these mean values for 1928-32 is 0·81 bushels.

CULTURAL TESTS WITH VARIOUS QUANTITIES OF SUPERPHOSPHATE APPLIED TO WHEAT.

Treatments and Technique:

(1) 20, 40, 60 lb. of P_2O_5, applied as 94 lb., 187 lb., 280 lb. respectively of superphosphate on land ploughed 3-4 months, 12 months, and 18 months before seeding.

(2) Cultural treatments in separate adjoining blocks, each 80 x 450 links.

(3) Fertilizer treatments randomized as a Latin square within each block.

Mean Annual Yields and Mean Yields for Four Seasons of Wheat with Varying Cultural and Fertilizer Treatments, 1927-30.

1. *Grain (bushels per acre).*

	I. Stubble-ploughed.				II. 12 months' fallow.				III. 18 months' fallow.			
Year.	No Phosphate.	20 lb. P_2O_5	40 lb. P_2O_5	60 lb. P_2O_5	No Phosphate.	20 lb. P_2O_5	40 lb. P_2O_5	60 lb. P_2O_5	No Phosphate.	20 lb. P_2O_5	40 lb. P_2O_5	60 lb. P_2O_5
1927	18·00	25·50	29·00	31·00	36·50	40·50	43·50	44·00	35·00	38·50	40·50	40·00
1928	22·33	25·86	26·58	27·89	25·60	27·43	30·12	31·30	20·75	28·22	30·58	31·30
1929	30·12	33·92	36·34	38·11	22·07	33·06	34·38	40·73	17·08	26·25	34·04	35·94
1930	32·08	39·42	38·83	40·79	27·56	38·37	41·58	44·07	19·91	38·37	41·71	44·85
Mean Yield, 1927–30.												
	25·63	31·18	32·69	34·45	27·93	34·84	37·39	40·03	23·19	32·83	36·71	38·02
Response to Fertilizer.												
	—	5·55	7·06	8·82	—	6·91	9·46	12·10	—	9·64	13·52	14·83

2. *Total Produce (lb. per acre).*

1927	2580	3610	4210	4240	5440	6810	7260	7500	5410	6450	6960	6890
1928	4494	5178	5438	6042	4691	5209	6137	6600	3520	5178	5814	6317
1929	3803	4306	4636	4919	3111	4542	4887	5806	2278	3976	4963	6042
1930	4793	5818	5881	6003	3736	5445	6255	6848	2683	5449	6121	6747
Mean Yield, 1927–30.												
	3918	4728	5041	5301	4244	5501	6135	6688	3473	5263	5964	6501
Response to Fertilizer.												
	—	810	1113	1383	—	1257	1891	2444	—	1790	2491	3028

DRILLING AND BROADCASTING PHOSPHATIC AND NITROGENOUS MANURES.

Treatments:

A. No fertilizer.
B. Superphosphate, 2 cwt. broadcast immediately after seeding.
C. Superphosphate, 2 cwt. drilled with the seed.
D. Superphosphate, 2 cwt. drilled + ammonium sulphate broadcast.
E. Superphosphate, 2 cwt., + ammonium sulphate, 1 cwt., drilled.
F. Diammonium phosphate, 83½ lb., + ammonium sulphate, 23½ lb. broadcast (combined dressing equivalent to 2 cwt. super. + 1 cwt. sulphate of ammonia).
G. Diammonium phosphate, 83½ lb., + ammonium sulphate, 23½ lb., drilled with the seed.

Technique:

Forty-nine plots, each 1/28th acre. Seven treatments, with seven replications randomized as a Latin square.

Comparison of Yields from Sepoy Wheat with Phosphatic and Nitrogenous Fertilizers (a) Drilled with the Seed, (b) Broadcast with the Drill on the Soil Surface.

Treatment.	Total Produce.			Grain Yield.		
	Yield per acre (cwt.).	Increase over unmanured plot.	Difference due to drilling with seed.	Yield per acre (bush.).	Increase over unmanured plot.	Difference due to drilling with seed.
A. No fertilizer	33·5	—	—	29·8	—	—
B. Super., 2 cwt. broadcast	46·8	13·3	—	39·5	9·7	—
C. Super., 2 cwt. drilled with seed	50·1	16·6	3·3	42·7	12·9	3·2
D. Super., 2 cwt. drilled; sulph. ammonia 1 cwt. broadcast	55·0	21·5	—	44·7	14·9	—
E. Super., 2 cwt.; sulph. ammonia, 1 cwt. drilled with seed ..	54·2	20·7	0·8*	44·1	14·3	0·6*
F. Diammonium phos., 83·5 lb.; sulph. ammonia, 23·5 lb. broadcast ..	49·3	15·8	—	41·2	11·4	—
G. Diammonium phos., 83·5 lb.; sulph. ammonia, 23·5 lb., drilled	53·4	19·9	4·1	45·1	15·3	3·9
Standard Error of Difference	—	—	0·74	—	—	0·62

Note: The differences marked * are not significant.

PHOSPHORUS AND NITROGEN ON WHEAT GROWN UNDER VARIOUS ROTATIONS.

Treatments:

(1) Fallow, Sepoy wheat, Early Burt oats, Pryor barley, Early Brunswick peas.

(2) No manure, superphosphate 2 cwt. per acre, superphosphate 2 cwt. + sulphate of ammonia 1 cwt. per acre.

Technique:

(1) Two blocks of 120 plots, each 1/34th acre.

(2) One block of 120 plots sown in random groups of five cropping treatments, namely, wheat, oats, barley, peas, fallow, each replicated six times with four plots per group. Each crop received 1 cwt. of superphosphate per acre, but not the six fallow groups.

The other block consisted of 120 plots of wheat sown after the groups of wheat, oats, barley, peas, and fallow plots of the preceding year.

Differential manurial treatment was given to each group of four wheat plots following the various crops and fallow.

The Effect of Phosphate and Phosphate + Nitrogen on the Yield of Wheat grown in rotation with (a) Wheat, (b) Oats, (c) Barley, (d) Peas, (e) Fallow.

Rotation.	Season.	No fertilizer.	2 cwt. super.	2 cwt. super + 1 cwt. sul. of ammonia.	Response to P	Response to N	Response to PN
Wheat after Wheat	1930	25·9	41·0	46·8			
	1931	14·9	19·2	28·3			
	1932	25·1	29·1	37·4			
	Mean	**22·0**	**29·8**	**37·5**	**7·8**	**7·7**	**15·5**
Wheat after Barley	1930	22·9	39·6	45·1			
	1931	14·3	20·3	29·9			
	1932	27·0	30·8	36·8			
	Mean	**21·4**	**30·2**	**37·3**	**8·8**	**7·1**	**15·9**
Wheat after Oats	1930	27·5	43·9	50·0			
	1931	15·3	20·6	27·2			
	1932	30·0	32·0	38·9			
	Mean	**24·3**	**32·2**	**38·7**	**7·9**	**6·5**	**14·4**
Wheat after Peas	1930	31·9	49·7	52·5			
	1931	21·5	32·8	40·2			
	1932	36·2	38·5	46·6			
	Mean	**29·9**	**40·3**	**46·4**	**10·4**	**6·1**	**16·5**
Wheat after Fallow	1930	37·5	55·6	54·8			
	1931	12·8	37·2	38·6			
	1932	33·6	49·7	49·7			
	Mean	**28·0**	**47·5**	**47·7**	**19·5**	**0·2**	**19·7**

Note: All increases in wheat yield due to nitrogen, phosphorus, phosphorus and nitrogen are significant, except that of nitrogen on wheat after fallow.

SUPERPHOSPHATE AND SULPHATE OF AMMONIA SINGLY AND IN VARIOUS COMBINATIONS ON WHEAT.

Treatments:

Dressings per acre: O = No manure; N_1 = 1 cwt. sulphate of ammonia; P_1 = 1 cwt. superphosphate; N_2 = 2 cwt. sulphate of ammonia; P_2 = 2 cwt. superphosphate; N_4 = 4 cwt. sulphate of ammonia; P_4 = 4 cwt. superphosphate.

Technique:

(a) Sixteen treatments, with six replications; 96 plots in all, in six randomized blocks.

(b) Plot treatments as follows: O, N_1, N_2, N_4, P_1, P_2, P_4, N_1P_1, N_1P_2, N_1P_4, N_2P_1, N_2P_2, N_2P_4, N_4P_1, N_4P_2, N_4P_4.

(c) Census studies were made on plots receiving the following treatment: O, P_2, P_4, N_2P_2, N_2P_4.

Mean Yield of Grain per acre from Wheat Treated with Various Combinations of Phosphates and Nitrogen, 1932.

Treatment.	Mean yield, bush./acre.	Increase over no manure.	Theoretical increase due to combined dressing (sum of individual dressings).	Difference between actual and theoretical increase due to combined dressing.
O	24·41	—	—	—
N_1	31·31	6·90	—	—
N_2	38·09	13·68	—	—
N_4	42·90	18·49	—	—
P_1	27·94	3·53	—	—
P_2	25·27	0·86*	—	—
P_4	29·19	4·78	—	—
N_1P_1	36·57	12·16	10·43	+1·73
N_1P_2	34·58	10·17	7·76	+2·41
N_1P_4	36·09	11·68	11·58	+0·10
N_2P_1	41·72	17·31	17·21	+0·10
N_2P_2	40·46	16·05	14·54	+1·51
N_2P_4	40·81	16·40	18·46	—2·06
N_4P_1	45·91	21·50	21·02	+0·48
N_4P_2	45·97	21·56	19·35	+2·21
N_4P_4	46·62	22·21	23·27	—1·06

General Mean = 36·74. S.E. of a difference = $\sqrt{2} \times 1{\cdot}10 = 1{\cdot}55$

Z for treatment is significant. * Difference not significant.

A contingency table shows that no real difference exists between the actual increases and the theoretical increases in the above table ($\chi^2 = 0{\cdot}69$, $P > 0{\cdot}99$), so that we must conclude that the responses to the dressings are additive.

SULPHATE OF AMMONIA ON BARLEY.

Treatments:

A. No nitrogen.
B. Sulphate of ammonia, 14 lb. per acre.
C. Sulphate of ammonia, 28 lb. per acre.
D. Sulphate of ammonia, 56 lb. per acre.
E. Sulphate of ammonia, 112 lb. per acre.
F. Sulphate of ammonia, 224 lb. per acre.
G. Sulphate of ammonia, 300 lb. per acre.
H. Sulphate of ammonia, 425 lb. per acre.
I. Sulphate of ammonia, 600 lb. per acre.

Technique:

(a) Nine treatments with nine replications of each treatment arranged in the form of a Latin square.

(b) Size of plots, 1/50 acre.

(c) Pryor barley, 75 lb. per acre, sown on July 25, 1930, with a basal dressing of 224 lb. superphosphate.

(d) Sulphate of ammonia top-dressed with the drill immediately after seeding.

(e) Nitrogen in the grain and straw of the barley crop determined at maturity.

(f) Plant establishment and tiller counts made on plots treated with no nitrogen and sulphate of ammonia 56 lb. per acre.

Mean Yields of Total Produce (cwt. per acre) and Grain (bush. per acre), 1930.

Dressing of Sulphate of Ammonia.	Total Produce. Cwt. per acre.	Total Produce. Increase due to Nitrogen.	Grain. Bush. per acre.	Grain. Response to Nitrogen (bush.).
Nil	43·9	—	47·5	—
14 lb. per acre ..	47·0	3·1	49·9	2·4
28 lb. per acre ..	50·6	6·7	53·4	5·8
56 lb. per acre ..	53·0	9·1	55·8	8·2
112 lb. per acre ..	58·5	14·6	60·9	13·3
224 lb. per acre ..	64·5	20·6	67·0	19·5
300 lb. per acre ..	67·7	23·8	69·9	22·4
425 lb. per acre ..	69·9	26·0	71·2	23·7
600 lb. per acre ..	69·6	25·7	70·7	23·2
Standard error ..	—	0·91	—	0·86

SULPHATE OF AMMONIA ON BARLEY (cont.).

Amount of Nitrogen Removed by Barley Treated with Various Quantities of Sulphate of Ammonia.

Sulphate of Ammonia applied. (lb. per acre).	Amount of Nitrogen applied as Fertilizer. (lb. per acre).	Amount of Nitrogen removed by Grain. (lb. per acre).	Amount of Nitrogen removed by Straw. (lb. per acre).	Total Nitrogen removed by Crop. (lb. per acre).	Extra Nitrogen taken in by Crop. (lb. per acre).
0	0	35·61	6·34	41·95	—
14	2·9	37·67	6·91	44·58	2·63
28	5·8	40·28	7·47	47·75	5·80
56	11·5	42·10	7·87	49·97	8·02
112	23·1	48·38	8·76	57·14	15·19
224	46·2	56·30	10·07	66·37	24·42
300	61·8	62·56	11·84	74·40	32·45
425	87·6	71·56	15·14	86·70	44·70
600	123·6	80·62	18·34	98·96	57·01

Plant Establishment, Tillering, Earing of Barley, with and without Sulphate of Ammonia.

Census Counts.	No Nitrogen.	Sulph. Ammonia 2 cwt. per acre.
1. Seeding (25/7/30):		
Average number of seeds sown per foot..	9·8	9·8
2. Plant establishment (24/8/30):		
Average number of plants per foot ..	8·9	8·7
3. Tillering (29/9/30):		
Average number of tillers per foot ..	26·8	30·2
4. Harvest (17/11/30):		
(a) No. of plants per foot	7·8	7·5
(b) No. of tillers per foot	31·0	41·4
(c) No. of ears per foot	16·8	23·9
(d) Percentage of tillers bearing ears ..	54%	58%
5. Yield of grain (bush. per acre)	47·5	67·0

UNIFORMITY TRIALS.

(1) *Trial with Wheat, Barley, and Oats, 1925.*

Yield of sixty unmanured plots, each ·05625 acre (approximately 1/18th acre), sown on bare fallow ploughed from virgin pasture, and arranged in four groups of 15 plots.

	Wheat.		Oats.	Barley.
Plot.	Nizam. lb. per plot.	Federation. lb. per plot.	Algerian. lb. per plot.	Cape. lb. per plot.
1	89·5	123·5	190·0	171·0
2	78·0	113·2	171·5	166·0
3	71·5	112·3	171·0	169·5
4	78·5	110·7	168·5	163·0
5	83·8	116·5	182·5	156·0
6	71·0	132·0	180·0	149·5
7	65·3	124·0	173·5	143·5
8	62·5	91·8	174·5	135·0
9	66·5	101·0	177·5	135·0
10	69·0	114·0	169·0	133·5
11	83·3	108·0	179·5	128·5
12	88·8	90·5	179·0	132·3
13	97·5	78·5	168·0	124·3
14	98·5	80·0	163·0	135·0
15	73·5	85·5	173·5	118·8
Mean Yield	78·5	105·4	174·7	144·1
Standard Deviation of the Mean	11·43 lb.	16·8 lb.	6·8 lb.	17·2 lb.
Standard Deviation per cent.	14·6%	15·9%	3·9%	12·0%

UNIFORMITY TRIALS (CONT.).

(2) *Uniformity Trial with Wheat, 1928.*

(a) Observed and Calculated Frequency Distribution of 360 plots of unmanured wheat, each 1/120th acre in area.

Classes. (lb. per plot).	No. of Plots. (Observed Frequency).	No. of Plots. (Calculated Frequency).
1·5–1·99	3	2·8
2·0–2·49	10	7·2
2·5–2·99	19	15·4
3·0–3·49	29	27·8
3·5–3·99	39	42·4
4·0–4·49	51	54·2
4·5–4·99	68	59·3
5·0–5·49	56	54·2
5·5–5·99	38	42·4
6·0–6·49	22	27·8
6·5–6·99	14	15·4
7·0–7·49	5	7·2
7·5–7·99	4	2·8
8·0–8·49	1	0·9
8·5–8·99	1	0·2
	360	360

(b) Yield of Grain from 72 successive 5-chain strips (1/24th acre) arranged in four groups of 18 plots.

1–18 lb. per plot.	19–36 lb. per plot.	37–54 lb. per plot.	55–72 lb. per plot.
17·94	27·44	20·85	22·41
14·42	25·23	22·94	23·37
18·06	23·17	19·45	23·03
21·11	25·73	16·49	21·59
20·87	28·78	16·06	19·43
21·44	25·67	18·63	20·82
19·72	27·56	22·71	23·68
20·15	32·65	26·07	27·11
19·98	22·42	23·74	30·05
18·50	21·95	21·75	28·70
27·10	24·36	23·96	30·44
24·88	23·88	23·40	32·06
25·84	23·35	25·75	26·98
25·39	23·18	24·81	25·86
24·38	23·63	22·19	26·95
22·10	21·34	20·36	27·62
20·15	21·21	21·02	26·57
28·71	17·94	18·32	22·71
Total 390·74	439·49	388·50	459·38

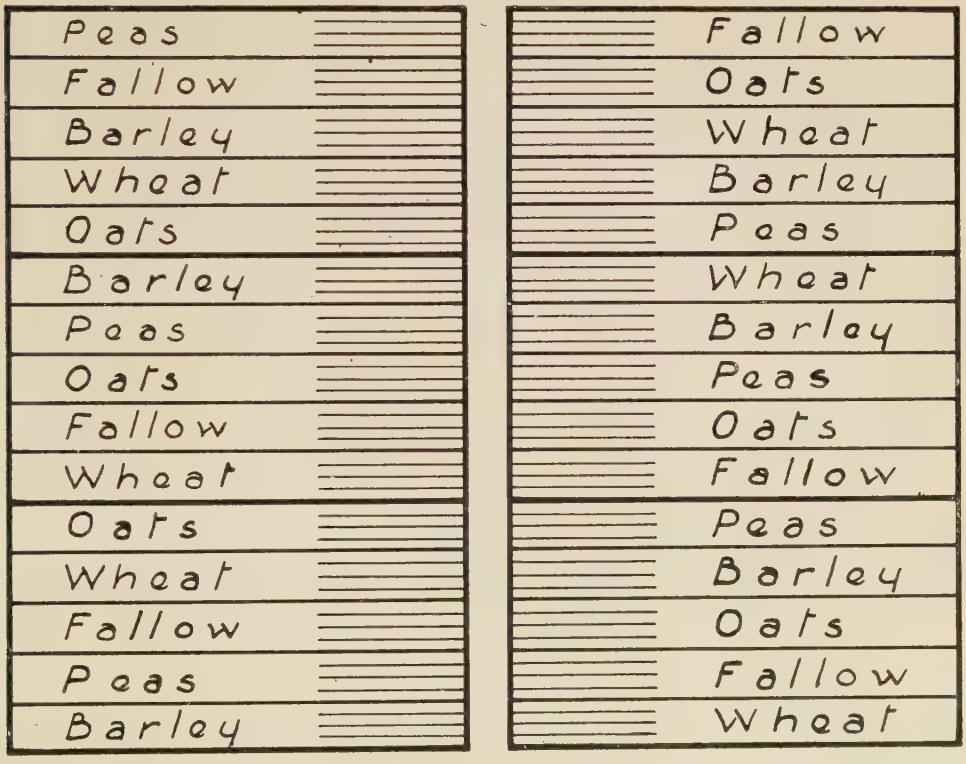
UNIFORMITY TRIALS (CONT.).

(c) Relationship of Standard Deviation to Size of Plot.

Size of Plot (acres).	Number of Unit Plots.	Number of Observations.	Standard Deviation %	Theoretical (Standard Deviation) n %
1/120	1	360	25·95	25·95
1/24	5	72	16·0	11·61
1/12	10	36	15·1	8·21
1/8	15	24	14·2	6·71
1/4	30	12	12·7	4·74
3/8	45	8	11·8	3·87
1/2	60	6	11·4	3·35

(3) *Uniformity Trial with Wheat, Barley, Oats, Peas, 1929.*

(a) Plan of field showing random arrangement of six groups, each of four plots, of wheat, barley, oats, peas, in preparation for a rotation manurial experiment with Wheat, 1929.



UNIFORMITY TRIALS (CONT.).

(b) Yield of Total Produce and Grain (lb. per plot) of Wheat, Barley, Oats and Peas. Unit plot, 1/34th acre.

Wheat.		Barley.		Oats.		Peas.	
Total Produce.	Grain.	Total Produce.	Grain.	Total Produce.	Grain.	Total Produce.	Grain.
130	60·5	158	78·0	141	76·4	64·5	32·5
129	58·5	170	83·0	174	82·2	62·5	33·5
124	56·0	175	85·5	169	77·3	69·5	37·0
120	52·5	167	82·5	165	78·3	61·5	34·5
139	60·5	149	74·5	144	68·8	73·0	36·0
148	63·5	157	78·0	116	56·4	62·0	32·0
148	62·0	145	71·5	171	81·4	53·0	27·0
140	60·0	156	76·0	172	82·0	51·0	25·0
140	61·0	167	81·5	179	86·2	60·0	31·5
144	62·5	159	76·0	176	84·7	65·0	33·0
153	66·0	137	68·5	196	88·4	63·0	32·0
147	63·0	154	76·5	165	76·6	66·0	33·5
139	55·5	157	75·5	171	73·9	69·5	39·0
153	65·5	151	68·5	175	79·4	55·0	29·5
125	55·0	150	72·5	168	80·5	70·5	37·5
126	52·5	161	75·5	194	78·2	67·0	36·0
146	62·5	179	88·0	193	90·4	77·5	40·0
144	58·5	176	80·5	182	84·3	79·5	39·5
137	60·0	176	83·5	206	84·9	82·5	41·0
143	61·5	170	69·0	171	83·5	82·5	40·5
157	63·0	154	79·0	187	79·6	70·5	37·0
153	64·0	164	78·0	194	89·0	68·0	35·5
132	56·5	170	75·5	190	86·4	75·5	41·0
140	59·5	171	73·0	190	88·5	69·5	37·0
Total 3,357	1,440	3,873	1,850	4,189	1,937·3	1,618·5	841
Mean 140	60·0	161	77·1	175	80·7	67·0	35·0

(c) Standard Deviation, expressed as a percentage of the yield for varying sizes of plot.

Size of Plot.	Wheat.		Barley.		Oats.		Peas.	
	Total Produce.	Grain.	Total Produce.	Grain.	Total Produce.	Grain.	Total Produce.	Grain.
Single plot ..	7·3	6·2	6·7	6·8	11·4	9·1	12·5	12·3
Double plot ..	7·1	5·4	6·2	5·4	10·0	8·3	11·7	11·4
Four adjacent plots	5·6	4·2	5·7	4·5	8·9	6·7	10·9	10·4

UNIFORMITY TRIALS (CONT.).

(4) *Uniformity Trials with Natural Pastures.*

Technique:

In September, 1928, an area of typical natural pasture was subdivided into unit plots 10 x 5 links in dimensions.

760 contiguous unit plots were harvested in four days, each plot being separately cut, the herbage air-dried and weighed. The accompanying table shows the mean yield per plot, together with the standard error of the mean yield for different plot sizes of natural pasture. Standard error expressed in grammes per plot and as a percentage of the mean yield.

Size of Plot.	No. of Plots.	Mean Yield per Plot. Grammes.	Standard Error of the Mean Yield per Plot. Grammes.	Standard Error of Single Plot. Grammes.	S.D.'s as % of Mean.	Theoretical S.D.'s as % Mean.
5 x10 links	720	221·7	± 2·684	± 72·02	32·48	—
5 x 20 ,,	360	441·9	± 6·289	±119·16	26·96	22·97
5 x 30 ,,	240	666·5	± 10·286	±159·02	23·86	18·75
5 x 60 ,,	120	1,325·0	± 24·115	±263·07	19·85	13·26
5 x 90 ,,	80	1,993·4	± 30·836	±274·08	13·75	10·83
5 x 180 ,,	40	3,986·8	± 77·293	±482·70	12·11	7·66
10 x 10 ,,	360	443·5	± 6·84	±129·63	29·23	29·97
10 x 20 ,,	180	884·4	± 16·51	±220·94	24·98	16·24
10 x 30 ,,	120	1,325·8	± 27·42	±299·16	22·56	13·26
10 x 60 ,,	60	2,657·8	± 61·73	±474·19	17·84	9·38
20 x 10 ,,	180	886·1	± 16·98	±227·24	25·64	16·24
20 x 20 ,,	90	1,767·7	± 42·20	±398·15	22·52	11·48
20 x 30 ,,	60	2,657·9	± 63·37	±532·80	20·05	9·38
40 x 10 ,,	90	1,771·1	± 43·38	±409·20	23·10	11·48
40 x 20 ,,	45	3,543·9	±107·50	±713·10	20·12	8·12
50 x 10 ,,	72	2,214·9	± 57·52	±484·64	21·88	10·27
50 x 20 ,,	36	4,429·8	±142·70	±844·21	19·06	7·26
100 x 10 ,,	36	4,429·8	±139·79	±821·12	18·54	7·26

TOP-DRESSING OF NATURAL PASTURE, WAITE INSTITUTE.

Area of plots: One acre.

Manurial Treatments:

Plot 1. Superphosphate, 185 lb. (40 lb. P_2O_5) per acre.
Plot 2. Superphosphate, 185 lb. + nitrate of soda, 78 lb. (12½ lb. N), per acre.
Plot 3. Nil.
Plot 4. Ground rock phosphate, 103 lb. (40 lb. P_2O_5) per acre.
Plot 5. Basic slag, 260 lb. (40 lb. P_2O_5) per acre.

(1) *Effect on Yield of Natural Pasture at the Waite Institute, 1925-32.*

Treatment.	Yield (cwt. air dry herbage per acre). 1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	Mean.
1. Superphosphate	27·74	43·20	28·54	39·63	33·70	30·32	47·50	75·66	40·79
2. Super. + Nitrate of Soda	30·69	43·57	27·95	41·81	37·45	39·86	63·12	81·11	45·70
3. Nil	21·76	28·35	18·00	24·31	17·69	20·67	41·43	56·92	28·64
4. Rock Phosphate	18·57	27·16	15·95	27·89	25·63	30·56	52·60	70·34	33·59
5. Basic Slag	25·49	49·15	24·84	35·58	35·31	43·56	58·06	78·25	43·78

(2) *Effect on Yield of Pasture Legumes (Annual Clovers) in the above natural pasture, 1925-32.*

Treatment.	Yield (cwt. air dry herbage per acre). 1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	Mean.
1. Superphosphate	20·25	20·17	4·29	23·00	14·45	1·71	6·80	9·35	12·50
2. Super. + Nitrate of Soda	18·35	16·66	0·40	13·78	8·24	0·45	2·79	7·33	8·50
3. Nil	6·57	9·49	1·02	0·90	2·18	0·39	3·56	9·94	4·26
4. Rock Phosphate	5·64	9·18	0·44	3·81	4·74	1·57	5·33	18·01	6·09
5. Basic Slag	14·35	19·12	2·43	4·28	13·30	1·63	5·18	12·58	9·11

(3) *Effect on Stock-carrying Capacity, 1928-32.*

Treatment.	Sheep-days of grazing per acre. 1928.	1929.	1930.	1931.	1932.	Mean
1. Superphosphate	900	877	813	1,271	2,421	1,256·40
2. Super + Nitrate of Soda ..	935	859	1,110	1,551	2,634	1,417·80
3. Nil	465	509	592	902	1,764	846·40
4. Rock Sulphate	640	603	667	1,072	2,215	1,039·40
5. Basic Slag	708	817	1,121	1,355	2,840	1,368·20
Rainfall, April-October ..	17·77	15·55	18·70	22·86	24·41	19·86

SULPHATE OF AMMONIA ON A SUBTERRANEAN CLOVER SWARD WITH REGARD TO (A) THE CARRYING CAPACITY IN COW DAYS, (B) THE ESTABLISHMENT OF SURFACE-SOWN RYE-GRASS.

Investigation conducted at Mount Barker, South Australia.
Average annual rainfall, 31·79 inches.

Technique:

(a) Eight paddocks, each of 2·25 acres in area, laid out on the ABBA plan.

(b) Four plots (A) receive superphosphate at the rate of 2 cwt. per acre per annum.

Four plots (B) receive 2 cwt. superphosphate per annum and 2 cwt. sulphate of ammonia per annum.

(c) Two herds of milking cows graze in rotation on the pasture. Herd A graze on Treatment A only, and Herd B on Treatment B only.

Each plot grazed for one week and rested for three weeks.

The number of cows in each herd adjusted to the amount of growth on each plot.

The Botanical Composition by Weight of a Typical Subterranean Clover Pasture before and after surface seeding of Perennial Rye-grass.

Herbage Species.	August, 1929. Phosphate only. %	May, 1932. Phosphate only. %	May, 1932. Phosphate + Nitrogen. %	November, 1932. Phosphate only. %	November, 1932. Phosphate + Nitrogen. %
Perennial rye-grass ..	0·4	15·0	54·3	27·1	44·9
Annual grasses ..	22·3	1·8	3·2	0·3	1·5
Subterranean clover ..	64·6	67·1	30·7	64·6	43·4
Miscellaneous plants ..	12·7	15·0	10·4	7·9	10·2
Bare ground, per cent...	14·2	1·1	1·4	0·1	Traces

The Number of Cow-days of Grazing obtained on the above pasture in the three seasons, 1930-32.

Season	1930.		1931.		1932.	
Treatment.	Phosphate only.	Phosphate + Nitrogen.	Phosphate only.	Phosphate + Nitrogen.	Phosphate only.	Phosphate + Nitrogen.
Total cow-days per acre ..	157	177	135	150	385	432
Cows per acre per annum..	0·431	0·485	0·373	0·412	1·055	1·184

SULPHATE OF AMMONIA ON THE YIELD OF A SEEDED PASTURE MIXTURE.

Pasture Mixture:

Hawke's Bay rye-grass, Wimmera rye-grass, *Phalaris tuberosa,* subterranean clover (Dwalganup), sown on 3rd June, 1930.

Treatments and Technique:

(a) Mixture sown in 16 drill strips, 400 x 9 links, with basal dressing of superphosphate, 2 cwt. per acre per annum.

(b) Drill strips treated in alternate pairs on the ABBA system, with nitrogen, 2 cwt. sulphate of ammonia per annum.

(c) Area cross-divided into 4 blocks each of 16 plots = 64 plots in all. These four blocks subjected to four systems of management, as follows:

Block A—Cut with horse-mower four times per annum, and the pasture removed from the block.

Block B—Cut as above, pasture weighed, sampled, and returned to plots for grazing by sheep.

Block C—Grazed by sheep without pre-cutting; sampled for yield in 1932.

Block D—Cut as hay at end of season and if necessary as aftermath.

Yield of Air-dry Herbage from Seeded Pasture under Different Systems of Pasture Management, Waite Institute, 1930-32.

Treatment.	1930. (cwt. per acre).	1931. (cwt. per acre).	1932. (cwt. per acre).	Mean 1930–32.
Section A—Systematic mowing:				
P—Phosphate only	40·95	20·90	38·13	33·33
PN—Phosphate + Nitrogen..	44·20	31·64	34·89	36·91
Difference due to N	3·25	10·74	—3·24	3·58
Section B—Mowing and grazing:				
P—Phosphate only	28·09	32·41	41·80	34·10
PN—Phosphate + Nitrogen..	32·02	42·64	45·66	40·11
Difference due to N	3·93	10·23	3·86	6·01
Section C—Grazing by sheep:				
P—Phosphate only	—	—	50·55	—
PN—Phosphate + Nitrogen..	—	—	60·34	—
Difference due to N	—	—	9·79	—
Section D—Cut as hay:				
P—Phosphate only	30·44	24·96	63·74	39·71
PN—Phosphate + Nitrogen..	37·32	45·58	62·36	48·42
Difference due to N	6·88	20·62	—1·38	8·71

Note: Standard errors (Md) of the various cuts throughout the three seasons were in the majority of cases below 5 per cent.

YIELD, BOTANICAL AND CHEMICAL COMPOSITION OF AN IRRIGATED PERMANENT PASTURE.

Technique:

(a) Pasture mixture of Hawke's Bay rye-grass, Akaroa cocksfoot, *Phalaris tuberosa*, and clover, sown on 5th September, 1930, on land previously under lucerne.

(b) Yield of pasture under rotational grazing by sheep measured by cuts from 12 protected quadrats, each of 1 sq. metre, for each treatment. Quadrats cut to 1 inch above ground level every 28 days, and placed on an adjacent area similarly cut to 1 inch above ground level.

(c) Material removed to laboratory for botanical analysis and dried in dehydrator.

(1) *Yield and Botanical Composition of a Permanent Pasture Grazed by Sheep at 28-day intervals during the first season of establishment.*

Date of Cutting.	Dry Matter.			Botanical Composition (per cent.).						
	Yield per quadrat. Gr.	Standard Error. %	Yield per acre. lb.	Rye-grass.	*Phalaris tuberosa*	Cocks-foot.	White and Alsike Clover.	Red Clover.	Lu-cerne.	Misc.
1931.										
Feb. 2	285·62	2·14	2,548·3	90·8	0·3	1·0	5·2	1·6	—	1·1
Mar. 2	203·13	3·45	1,812·3	84·0	1·4	3·1	7·1	3·2	0·8	0·4
Mar. 30	181·03	2·24	1,615·1	74·1	1·5	1·7	8·0	11·4	2·2	1·1
April 27	141·75	2·57	1,264·7	63·8	3·5	2·7	6·3	19·7	—	4·0
May 25	115·24	3·49	1,028·2	59·6	1·6	1·5	13·0	20·3	0·8	3·2
June 22	76·84	4·18	685·6	77·2	1·6	2·0	9·2	7·6	—	2·4
July 20	59·18	3·83	528·0	75·0	1·6	2·0	8·4	9·4	0·2	3·4
Aug. 17	64·01	5·08	571·1	65·3	2·1	3·3	11·5	13·8	0·2	3·8
Sept. 14	110·95	3·66	989·9	60·1	1·8	1·8	14·7	13·9	0·1	7·6
Oct. 12	259·92	4·49	2,319·0	44·9	1·1	2·7	20·2	22·4	—	8·7
Nov. 9	224·49	3·03	2,002·9	40·4	0·8	3·5	36·3	16·2	0·1	2·7
Dec. 7	224·72	2·43	2,005·0	45·4	1·0	4·7	24·6	23·3	—	1·0
1932.										
Jan. 3	235·77	3·15	2,103·5	46·8	1·0	9·3	19·0	22·9	—	1·0

IRRIGATED PERMANENT PASTURE (CONT.).

(2) *Yield of Pasture expressed as Dry Matter per acre from Plots (a) Grazed by sheep, (b) Mown at intervals of 28 days.*

Date of Cutting.	Grazed. Monthly Cut. lb. per acre.	Grazed. Standard Error. %	Grazed. Cumulative Total Yield. lb. per acre.	Mown. Monthly Cut. lb. per acre.	Mown. Standard Error. %	Mown. Cumulative Total Yield. lb. per acre.
1931.						
May 25	1,028·2	3·49	1,028·2	1,037·4	2·92	1,037·4
June 22	685·6	4·18	1,713·8	530·1	6·74	1,567·5
July 20	528·0	3·84	2,241·8	483·0	5·22	2,050·5
Aug. 17	571·1	5·08	2,812·9	394·5	4·39	2,445·0
Sept. 14	989·9	3·67	3,802·8	764·7	3·33	3,209·7
Oct. 12	2,319·0	4·49	6,121·8	1,574·1	4·51	4,783·8
Nov. 9	2,002·9	3·03	8,124·7	1,648·9	2·38	6,432·7
Dec. 7	2,005·0	2·43	10,129·7	1,804·7	3·02	8,237·4
1932.						
Jan. 4	2,103·5	3·15	12,233·2	1,143·5	4·84	9,380·9
Feb. 1	1,548·3	3·67	13,781·5	1,322·2	3·26	10,703·1
Feb. 29	1.628·6	2·97	15,410·1	914·5	3·14	11,617·6
Mar. 29	1,550·0	1·73	16,960·1	1,158·9	1·31	12,776·5
April 26	1,168·6	3·07	18,128·7	765·5	3·63	13,542·0

(3) *Yield of Pasture expressed as Dry Matter per acre under Monthly (28 days) and Bi-monthly (56 days) Cutting.*

Date of Cutting.	Monthly Cuts (28 days).		Date of Cutting.	Bi-monthly Cuts (56 days).
1931.				
May 25	949·1			
June 22	265·8			
		1,214·9	June 22	1,282·0
July 20	300·7			
August 17 ..	212·3			
		513·0	August 17 ..	1,170·0
September 14 ..	588·4			
October 12 ..	1,471·6			
		2,060·0	October 12 ..	2,774·7
November 9 ..	2,022·9			
December 7 ..	1,709·9			
		3,732·8	December 7 ..	4,494·2
1932.				
January 4 ..	1,283·8			
February 1 ..	931·8			
		2,215·6	February 1 ..	2,761·4
February 29 ..	326·2			
March 29 ..	985·6			
		1,311·8	March 29 ..	1,986·4
April 26 ..		1,035·1	April 26	972·2
Total for twelve months ..		12,083·2	Total for twelve months ..	15,540·9

IRRIGATED PERMANENT PASTURE (CONT.).

(4) *Percentage of Phosphoric Acid and Nitrogen in Dry Matter of Herbage (a) Rotationally grazed by sheep at intervals of 28 days, (b) Mown at intervals of 28 days, (c) Mown at intervals of 56 days.*

Date.	Grazed Quadrats.		Monthly Mown Section.		Bi-monthly Mown Section.	
	P_2O_5. %	Nitrogen. %	P_2O_5. %	Nitrogen. %	P_2O_5. %	Nitrogen. %
1931.						
February 2	0·85	2·41	—	—	—	—
March 2	1·05	3·24	—	—	—	—
March 30	1·14	3·42	—	—	—	—
April 27	1·23	3·31	—	—	—	—
May 25	1·34	4·28	1·44	4·22	—	—
June 22	1·29	4·41	1·27	4·01	1·30	3·56
July 20	1·19	4·39	1·21	3·76	—	—
August 17	1·26	4·68	1·32	4·05	1·18	3·37
September 14 ..	1·24	4·27	1·23	4·18	—	—
October 12	1·13	3·45	1·14	3·73	1·00	3·07
November 9	1·09	3·75	1·12	3·89	—	—
December 7	0·96	3·28	0·90	3·19	0·83	2·65
1932.						
January 4	0·94	3·53	1·00	3·68	—	—
February 1	0·91	3·48	1·00	3·79	0·76	3·07
February 29	0·90	3·65	1·03	3·59	—	—
March 29	0·90	3·82	1·15	3·74	0·90	3·38
April 26	1·12	4·18	1·39	3·44	1·17	3·53
Mean percentage:						
February 2, 1931, to January 4, 1932	1·13	3·73	—	—	—	—
May 25, 1931, to April 26, 1932 ..	1·10	3·94	1·17	3·79	1·02	3·23
Weighted averages:						
February 2, 1931, to January 4, 1932	1·08	3·49	—	—	—	—
May 25, 1931, to April 26, 1932 ..	1·06	3·77	1·13	3·73	0·94	3·06